A TEXT BOOK

OF

PUNJAB AGRICULTURE.

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GLOSSARY.

Anbi-godi	"Blind hoeing," *i. e.*, before plants (generally sugarcane) appear above ground.
Arti	Commission agent, p. 110.
Ata	Wheat meal.
Badshah	King.
Baguri	*Hand-hoe for blind hoeing of sugarcane.*
Bair	Wooden drum of a Persian-wheel.
Bar	An arid tract.
Bara	A very hard type of heavy alkaline soil, p. 3.
Bari	Similar to Bara, but less hard.
Barani	Rain-watered.
Bahaduri	Gram caterpillar, p. 156.
Bengals	Commercial name of a low grade of Indian cotton.
Berra	Wheat and gram grown in mixture.
Bet	Riverain tract.
Bhari	Bundle.
Bharola	Cylindrical mud bin for storing grain.
Bhusa	Also "turi" means crushed wheat straw, p. 104.
Bhusa-missa	Crushed gram straw after threshing.
Band	See "wat."
Candy	The Bombay candy of cotton is 784 lbs. or 9½ mds. of lint or two bales nett.
Chahi	Well-irrigated.
Chak	Group of rectangles or squares in canal colonies, p. 7:.
Chakkal	*Horizontal toothed disc of the Persian-wheel, p. 65.*
Chakli	Cog-wheel of the Persian-wheel.
Chait	March-April, name of one of the Indian months.
Chapati	A thin loaf of bread.
Charsa	Leather bucket or bag for lifting water from wells.
Chhaj	Flat winnowing basket.
Chhatta	Broadcast sowing, p. 40.
Chhiklis	Bullock muzzles.
Chow	Wooden breast or mouldboard of "munah" plough, p. 47.
Cusec	Technical irrigation term meaning cubic foot of water per second.
Dáb	See p. 37.
Dál	Split pulses.
Desi	Country; indigenous.
Dhan	Unhusked rice, p. 118.
Dhar	Long low heaps of stored "bhusa" covered with mud.

Dharwar	...	Part of the Bombay Presidency growing American cotton since 1860, p. 132.
Dranti	...	*Also "datri" or "dati," sickle.*
Duty	...	A technical irrigation term to express relation between area of crop grown and water used.
Fakir	...	Beggar.
Fellah	...	Egyptian cultivator.
Gandala	...	Also "chuha-ramba," hole-digger, p. 56.
Godi	...	Interculture after cultivation.
Goji	...	Gram and barley grown in mixture.
Gur	...	Raw sugar in lumps.
Hal	...	Form of wooden plough used in the Punjab, p. 46.
Hale	...	Beam of the "hal," p. 47.
Haq	...	Right, generally percentage area of irrigation guaranteed.
Hathi	...	Handle of the plough.
Hithar	...	Low-lying lands, p. 89.
Hukkah	...	Indian pipe.
Jandra	...	Ridging rake, p. 56.
Jhallar	...	Form of Persian-wheel for tanks or rivers.
Jhul	...	Rough horse-blankets.
Kabuli	...	From Kabul in Afghanistan.
Kahi	...	Also "kasi"; a spade, p. 56.
Káhi	...	*Saccharum spontaneum.*
Kallar	...	Also "reh" or "usar"; alkaline incrustation on soil.
Kalrathi	...	Heavy alkaline soil.
Kan	...	Proportion of lint in seed cotton.
Kanal	...	⅛th of an acre.
Kapas	...	Seed cotton.
Karah	...	Leveller.
Karand	...	Also "papri"; hard crust formed on the surface of soil after rain or irrigation.
Kasola	...	Small spade.
Kera	...	Dropping seed in the furrow behind the plough, p. 41.
Khal	...	Water-course.
Kharaba	...	Remission of land revenue and water rate.
Khapra	...	Larva of *Trogoderma khapra*, p. 106.
Kharif	...	Monsoon or summer crops.
Khurpa	...	Also "ramba"; hand-hoe, p. 56.
Kiari	...	Also "kiara"; compartment of a field for irrigation.
Kikar	...	*Acacia arabica.*
Killa	...	1/25th of a square. In Lower Chenab Canal=1·1 acres, and in Lower Bari Doab Canal=1 acre.
	...	Toggle or wooden pin.

Kor	... First watering after sowing.
Kothi	... Rectangular mud bin for storing grain.
Kulhari	... Axe, p. 56.
Kur	... Main working part of the "hal."
Kup	... See "musal."
Lalkasarwali	... Bearded red-awned wheat, *e.g.*, No. 11.
Leeping	... Rubbing over with cow-dung; cotton seed is thus treated before sowing.
Lambardar	... Village headman, p. 11.
Mahl	... Rope ladder of the Persian-wheel.
Maira	... Sandy soil.
Mandi	... Market.
Maria	... $\frac{1}{20}$th of a kanal or $\frac{1}{160}$th of an acre.
Mat	... Large earthen pitcher.
Maund	... $82\frac{2}{7}$ lbs. or 40 seers.
Mohla	... Pestle, p. 118.
Mote	... Charsa, p. 68.
Munah	... A form of native plough in use in the Punjab, p. 46.
Murabba	... A square of land measuring 25 "killas" or acres as the case may be.
Musal	... Also "kup," a conical stack of stored "bhusa" generally thatched with straw.
Mussalman	... Muhammedan.
Nali	... See "por."
Neem	... *Melia Azadirachta*
Nehri	... Canal irrigated.
Nili Bar	... An arid tract in the Multan and Montgomery Districts.
Oker	... Irregular, p. 47
Oomras	... Commercial name of a Central Indian cotton of medium staple.
Pahar	... Turn of water of 3 hours.
Pahora	... Wooden rake.
Panjali	... Yoke.
Panj-danta	... Horse-hoe, p. 51.
Palla	... Cylindrical stacks of stored "bhusa" thatched with mud.
Patwari	... Village revenue or irrigation subordinate.
Phallah	... Share of a plough, p. 47.
Phalla	... A hurdle dragged by bullocks in wheat threshing.
Por	... Also "nali," a seed tube with funnel-shaped mouth attached behind the plough for sowing.
Pora	... Sowing with the "por," p. 42.
Pucca	... Masonry.
Punjabi	... Pertaining to the Punjab.
Rāb	Partly boiled cane juice fit for making sugar.

Rabi	...	Winter crops.
Rahat	...	Persian-Wheel.
Rajbaha	...	Canal distributary.
Ramba	...	See "khurpa."
Ramio kos	...	Common charsa.
Ranni	...	Watering applied shortly before sowing.
Reb	...	See "kallar."
Ság	...	Pot-herbs; vegetables.
Sailab or sailaba	...	Lands subject to periodical or annual floods.
Sanga	...	Wooden fork, p. 56.
Sannah	...	Front of the beam of a "hal."
Ser	...	$\frac{1}{40}$th of a maund, approximately 2 lbs.
Shakkar	...	Raw sugar.
Sohaga	...	Levelling beam; wooden beam used in breaking clods and covering seed, p. 53.
Suklai	...	Bark of the tree (*Kydia calycina*, Rox.), p. 143.
Sundi	...	Larval stage of certain insects.
Sundhio kos	...	Self delivering charsa, p. 67.
Susri	...	Any small beetle attacking stored grain, *e.g.*, *Calandra oryzæ* and *Rhizopertha dominica*.
Tahsil	...	Part of a district, p. 11.
Tahsildar	...	Officer in charge of a tahsil, p. 11.
Tarangli	...	5 to 7 pronged iron fork with wooden handle, p. 56.
Tela	...	Small sucking insects, *e.g.*, aphis.
Theka	...	Bin made of sacking for storing grain.
Tilli	...	White variety of "til" or gingelly.
Toka	...	Fodder cutter or chopper.
Ukhli	...	Mortar.
Usar	...	See "kallar."
Wadanak	...	Macaroni wheat (*Triticum durum*), p. 94.
Wadh	...	Stubble.
Wahn	...	Water applied to a field to enable it to be ploughed.
Wari	...	Turn of irrigation, p. 72.
Wat	...	Also "bund," irrigation ridges.
Wattar	...	Right condition of land for ploughing after rain or watering.
Wazir	...	Minister.
Zaid kharif	...	Autumn crops, *e.g.*, "toria."
Zaid rabi	...	Spring crops, *e.g.*, melons.
Zail	...	One of the divisions of a tahsil.
Zaildar	...	Non-official who helps in the work of running a zail
Zamindar	...	Farmer, may be tenant or owner.

ERRATA.

Page.						
1	Line	8	*for*	" Lahor "	*read*	" Lahore ".
1	,,	9	,,	" Capitae "	,,	" Capital ".
1	,,	10	,,	" extremel "	,,	" extremes ".
15	,,	8	,,	" th "	,,	" the "
17	,,	1	,	,, flesh "	,,	" flesh ".
18	,,	last	,,	" th "	,,	" the ".
26	,,	4	,,	" w ll "	,,	" will ".
26	,,	9	,,	" severa "	,,	" several ".
26	,,	10	,,	" i "	,,	" it ".
35	,,	20	,,	" tinned "	,,	" tined ".
36	,,	13	,,	" tinned "	,,	" tined ".
36	,,	4	,,	" have "	,,	" leave ".
38	2nd heading		,,	" pl ugh "	,,	" plough ".
45	Line	6	,,	" metheds "	,,	" methods ".
46	,,	last	,,	" adopted "	,,	" adapted ".
55	,,	32	,,	" acres "	,,	" seers ".
56	,,	27	,,	" othe "	,,	" other ".
58	,,	16	,,	" Sugarcaue "	,,	" Sugarcane ".
60	,,	12	,,	" except "	,,	" expect "
60	,,	foot-note	,,	" Leath "	,,	" Leather's ".
60	,,	,,	,,	" emoirs "	,,	" memoirs ".
61	,,	last	,,	" grear "	,,	" great ".
66	,,	17	,,	" Th "	,,	" The ".
66	,,	18	,,	" o "	,,	" of ".
67	,,	13	,,	" 1 "	,,	" 10 ".
70	,,	30	,,	" wel "	,	" well ".
74	,,	1st heading	,,	" paynent "	,,	" payment ".
77	,,	10	,,	" An ther "	,	" Another ".
79	,,	9	,,	" ow "	,,	" low ".
79	Table IV, line 2		,,	" Gr m "	,,	" Gram ".
79		*read*		" Table IV "	*instead*	" V ".
83	Table 2nd, line 2		,,	" S nji "	*read*	" Senji ".
92	Line	18	,,	" soi "	,,	" soil ".
94	,,	19		" tota "	,,	" total ".

PAGE.

103	Line	3	*for*	"car"	*read*	"can".
104	,,	1	,,	"genera"	,,	"general".
106	,,	13	,,	"mean	,,	"means".
106	,,	38	,,	"st adily"	,,	"steadily".
106	,,	last	,,	"domplete"	,,	"complete".
107	,,	22	,,	"larvœ"	,,	"larvæ."
109	,,	11	,,	"inna"	,,	"anna".
115	,,	11	,,	"it"	,,	"is".
115	,,	12	,,	"wheas"	,,	"wheat".
118	,,	5	,,	"croppee".	,,	"cropped".
127	3rd heading		,,	"piked"	,,	"picked".
133	Line	38	,,	"nelectum"	,,	"neglectum".
134	,,	32	,,	"Sinc"	,,	"Since".
139	,,	2	,,	"Saccha am"	,,	"Saccharam".
142	1st heading		,,	"Hoei ghoed"	,,	"Hoeing".
144	4th heading		,,	"s gar"	,,	"sugar".
150	Line	3	,,	"prep red"	,,	"prepared".
153	2nd heading		,,	" iseases"	,,	"Diseases".
158	Line	10	,,	"acr s"	,,	"acres".
163	1st Table		,,	" 3·6"	,,	"3·6".
166	Line	12	,,	"g ing"	,,	"going".
169	,,	3	,,	"s"	,,	"is".
169	,,	4	,,	"n"	,,	"in".
169	,,	19	,,	"i"	,,	"is".
170	,,	16	,,	"Brassi a"	,,	"Brassica".
171	,,	30	,,	"wel"	,,	"well".

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INTRODUCTION.

Agriculture has long been, and is no less to-day, the means by which man has obtained the most important necessities for his life and comfort. It is a business involving the production and sale of certain commodities required by the community, usually for food or clothing.

The successful farmer has to learn not only from experience on his own farm, but also by looking further afield. Practices exist in one part of a district or tract which are not generally known, but which may often be adopted in other parts. New conditions are constantly arising in the world's markets which render new crops or products more profitable relatively than before. Again in the Punjab the spread and development of irrigation is opening up new fields and new conditions which render the older methods of farming unprofitable and obsolete. American cotton first tried in the Punjab in 1902 in a systematic manner is now grown over half a million acres annually. There are good prospects that a better variety than 4F will be grown if the relative price of long staple cotton is maintained in Liverpool and Bombay. The work of the Agricultural Department in improving cultivation by line cultivation and the introduction of simple country made implements bids well to revolutionise present methods of farming, and will enable the farmer better to face the increasing cost of hand labour. Improved agriculture does not merely mean growing pure seed in place of present mixtures, important as that is as a preliminary measure, but concerns all farming operations where a profitable saving can be made. A close study of costs must guide the farmer in the adoption of even the smallest improvement. One of the main objects of this book is to encourage such a study as the safest basis for the future stability and progress of Punjab Agriculture. The progressive farmer must continue to progress for the so-called scientific agriculture of to-day is often the ordinary practice of to-morrow.

This book is intended mainly for students and teachers of agriculture in the schools. It is hoped, however, that it may be found useful by Revenue and Irrigation Officers, business Firms dealing in agricultural produce, and the general public. A book of this kind must of necessity have many defects. We hope that on the whole it may be found useful and practical.

We are indebted to several colleagues at Lyallpur for help, particularly to Mr. Wilsdon, for chemical analysis, etc., to Labh Singh for information *re* weeds, and to Tehl Ram for laborious work in checking figures, preparing a glossary, and several criticisms of value. The illustrations were prepared by the artist kindly lent by the Botanical Section.

W. ROBERTS.

O. T. FAULKNER

PART I.—GENERAL.

COIMBATORE

CHAPTER I.—GENERAL FEATURES OF THE PROVINCE.

The Punjab is a province in North-West India comprising an area of 133,000 square miles, of which 36,500 belong to Native States. It thus forms a tenth of the area of the Indian Empire and is larger by one-tenth than the British Isles. It lies between 27° 39′ and 34° 2′ N. and 69° 23′ and 79° 2′ E. The latitude of Gibraltar in the south of Spain is 36°, or only 2° further north from the Equator than Attock in the north of the Punjab and 5° further north than Lahor s The Punjab is, however, an inland province with its capitae. Lahore, 750 miles from the sea, and is hence subject to extremel, of temperature of the continental character.

Physical divisions.* The province falls into five main physical divisions, of which two—*viz.*, the Himalayan and the Salt Range arid plateau, are less important from an agricultural point of view. The remaining three are—

(*a*) The sub-montane, including stations such as Ambala, Ludhiana, and Sialkot, forming the richest part of the province.

(*b*) The Indo-Gangetic Plain West extending eastward as far as Lahore.

(*c*) The south-western arid plains, comprising Mianwali, Sind Sagar, Muzaffargarh, Dera Ghazi Khan, and Multan.

The last two divisions are of vast extent and depending almost entirely on canal irrigation for their prosperity.

The Punjab, barring the montane and parts of the sub-montane tract, is in the main a vast level alluvial plain with a gentle slope of about 2 feet per mile from east to west.

The province is fortunate in having seven large rivers passing through it or along its boundaries. These are (1) the Jumna, forming its eastern boundary for 200 miles and flowing into the Bay of Bengal, (2) the Sutlej, which enters the

plains at Rupar and joins the Beas at Sobraon; (3) the Beas, which enters the plains just south of the Ravi, and then turns south and joins the Sutlej; (4) the Ravi, which reaches the plains below Dalhousie and joins the combined rivers of the Chenab and Jhelum 50 miles south of Jhang; (5) the Chenab, which reaches the plains east of Jhelum and joins the Jhelum river 225 miles further west; (6) the Jhelum, which enters the Punjab east of the Salt Range and joins the Chenab at Jhang; (7) the Indus, which is the largest of all, and traverses partly through the province and on its boundary. The combined Sutlej and Beas join the combined Jhelum, Chenab, and Ravi 8 miles north of Uch, 270 miles south-west of Sobraon. The combined five rivers join the Indus at Punjnad in the south-west Punjab.

Of the seven rivers affecting the Punjab, therefore, six ultimately join within the province. These rivers derive their supply of water mainly from melting snow in the Himalayas, and are in flood from April to September, when they carry enormous volumes of water. Their minimum winter supplies vary from 1,300 cusecs in the case of the Ravi to 18,000 cusecs in the case of the Indus at Attock.*

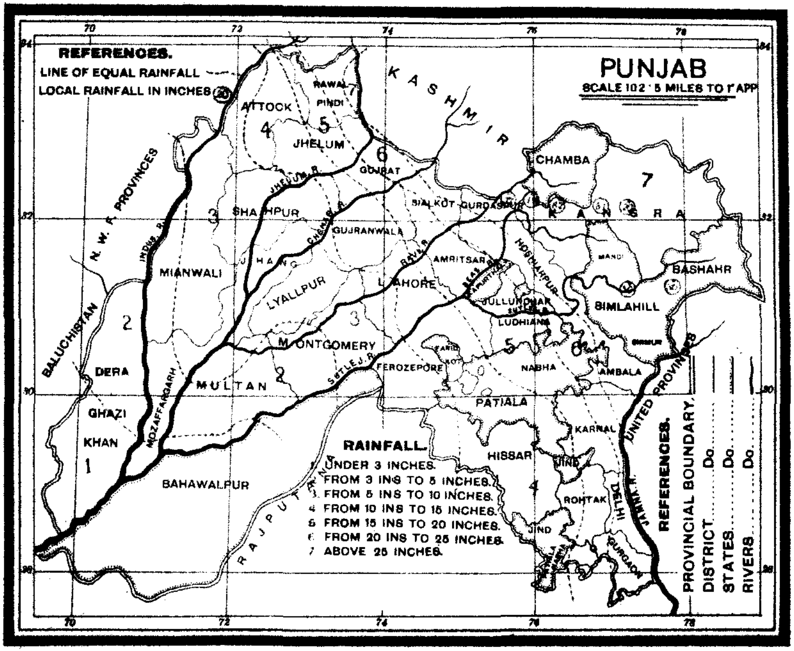
---

* *Note by Mr. H. W. Nicholson, Punjab Irrigation.*

Statement showing reported discharges of the Punjab Rivers.

River.	Site.	Minimum.	Maximum.
Jumna	Tajewala	2,167	2,50,000
Sutlej	Rupar	2,818	2,60,000
Beas	Nowshera	2,800	3,25,000
Ravi	Madhopur	1,300	2,00,000
Chenab	Khanki	3,884	6,00,000
Jhelum	Rasul	4,500	5,00,000
Indus	Attock	18,000	10,00,000

The maximum flood means nothing to any one except the engineer who has to design to pass that supply, which at the most will only be realised once in 30 years, say, for a few hours. The supply from April to September is, however, generally from five to ten times the minimum winter supply.


PUNJAB
SCALE 102·5 MILES TO 1" APP
REFERENCES.
LINE OF EQUAL RAINFALL
LOCAL RAINFALL IN INCHES
RAINFALL.
1 UNDER 3 INCHES.
2 FROM 3 INS TO 5 INCHES.
3 FROM 5 INS TO 10 INCHES.
4 FROM 10 INS TO 15 INCHES.
5 FROM 15 INS TO 20 INCHES.
6 FROM 20 INS TO 25 INCHES.
7 ABOVE 25 INCHES.
REFERENCES.
PROVINCIAL BOUNDARY.
DISTRICT Do.
STATES Do.
RIVERS Do.
KASHMIR
N. W. F. PROVINCES
BALUCHISTAN
UNITED PROVINCES
RAJPUTANA
ATTOCK
RAWAL PINDI
JHELUM
GUJRAT
SHAHPUR
GUJRANWALA
SIALKOT
GURDASPUR
CHAMBA
KANGRA
MANDI
BASHAHR
SIMLAHILL
SIRMUR
AMRITSAR
HOSHIARPUR
JULLUNDHAR
LUDHIANA
LAHORE
LYALLPUR
JHANG
MIANWALI
MONTGOMERY
MULTAN
MOZAFFARGARH
DERA GHAZI KHAN
BAHAWALPUR
FEROZEPORE
FARIDKOT
NABHA
PATIALA
AMBALA
KARNAL
JIND
HISSAR
ROHTAK
DELHI
GURGAON
INDUS R.
JHELUM R.
CHENAB R.
RAVI R.
BEAS R.
SUTLEJ R.
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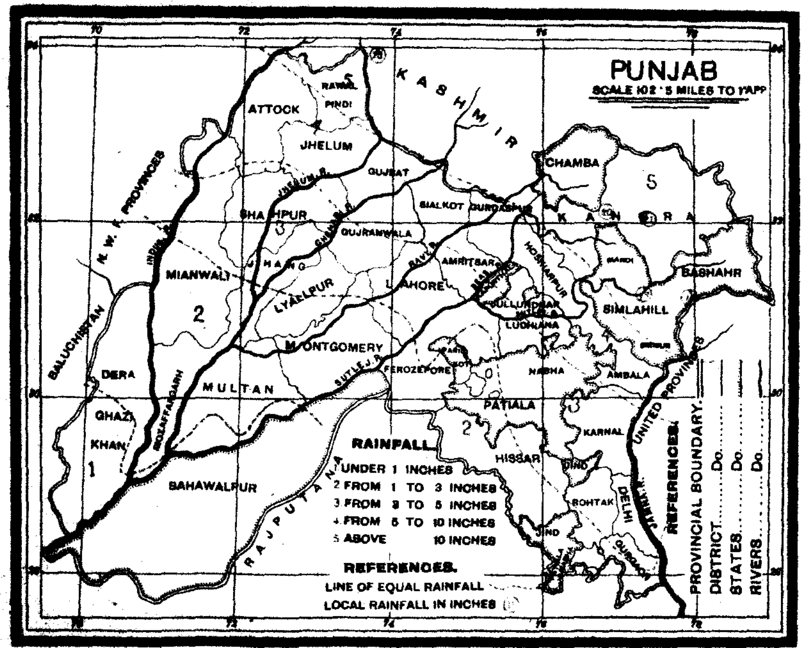
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1 UNDER 1 INCHES
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5 ABOVE 10 INCHES
REFERENCES.
LINE OF EQUAL RAINFALL
LOCAL RAINFALL IN INCHES
REFERENCES.
PROVINCIAL BOUNDARY.
DISTRICT .... Do.
STATES .... Do.
RIVERS .... Do.

Climate.

Over the greater part of the Punjab, summer temperatures are very high and winter temperatures very low. In December and January the temperature at night is often below freezing point, and crops may be damaged by frost as early as 20th November or as late as February 15th. The day temperature in winter seldom rises above 75° F. From February onwards the temperature generally rises 10° F. per mensem until it reaches 115° F. to 121° F. in June, the night temperature averaging 81° F.

Rainfall.

The Punjab has two well-defined rainy seasons. The south-west monsoon reaches the Punjab at the end of June, and most parts only get rain about middle of July. Most of the rain falls in the submontane and montane areas, and very little generally falls in the dry south-west tracts. The summer rains generally cease about the middle of September or earlier.

The north-east depression gives rain from December to middle of March, and is on the whole much better distributed than the south west supply. The total rainfall in the winter, however, is generally much smaller than in summer. The yearly rainfall decreases rapidly as we pass westwards away from the hills. In the Himalayas it is nowhere less than 36 inches, and in places like Dharmsala may average over 100 inches. The eastern plains from Delhi to Lahore average 24 inches. West of Lahore the rainfall falls rapidly to 12 inches at Lyallpur, 8 inches at Jhang, and 5 or 6 inches at Multan and westwards of Multan. During the summer season heavy cyclonic storms are sometimes experienced with a fall of over 6 inches rainfall in 24 hours causing some damage to crops. Hails torms do damage occasionally in late summer or in April, but the effect is generally very local. Maps A and B show distribution of kharif and winter rainfall.

Soil.

The soil of the Punjab plains is practically all alluvial or deposited from the rivers. It forms a part of the great Indo-Gangetic plain. In consistency it is generally a sandy loam.

Heavy clay is found in wet rice tracts and in a long strip reaching from Gurdaspur to Khanewal along the Ravi. This latter soil is called *bara* or *bari*, and is barren in most cases. In Montgomery District on the Lower Bari Doab Canal, it occupies an area of 100,000 acres "bara" and 75,000 acres "bari" land. Very sandy soils are found in Mianwali and in parts of the Sind Sagar Doab.

The table below shows the main statistical information as compared with the United Kingdom—

Statistics.

	1	2	3	4	5	6
	Area according to survey.	Native States.	Net area according to village papers.	Cropped area.	Culturable waste and fallow.	Net available for cultivation, including forests.
	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
* Punjab, 1917-18 ...	86,000,000	24,500,000	60,000,000	27,000,000	18,000,000	14,500,000

	United Kingdom.	Ireland.	Great Britain.			
	Area.	Area.	Total area.	Crops and grass.	Permanent grass.	Arable land.
†United Kingdom of Great Britain and Ireland, 1917.	76,638,994	20,247,294	56,207,247	31,857,804	17,251,136	14,606,668

NOTE.—In column (3) the areas for which no returns are available are included, and this amounts to roughly 5 million acres consisting of Simla and Kangra mountain areas and river beds of Gurgaon.

It will be seen that the total area of the United Kingdom is similar to that of the Punjab, and the area of Great Britain is similar to that of the Punjab, excluding Native States. Of the area returned as culturable in Great Britain more than half is under grass. This in the Punjab would be termed culturable waste or fallow. Grass land in Britain often pays better than cultivation. Of the cultivated area of 14½ million acres in Great Britain wheat occupies 2 million acres, barley 1½ million, and oats over 3 million acres as compared to 9 million acres wheat in the Punjab. In live stock the main differences relate to horses, of which there are nearly 2 millions in Great Britain as compared to 350,000 in the Punjab. There are 29 million sheep as compared to 4½ million in the Punjab.

It is roughly estimated that 30 rupees per acre is sufficient capital for farming in the Punjab, whereas £15 is required in Britain, or at present exchange values of 1*s*. 5*d*. to the rupee it takes eight times as much capital to farm in Britain as in the Punjab. Manures are largely used in Britain for crops and

* Agricultural Statistics of India.

† Journal of the Royal Agricultural Society of England, Volume 78, 1917.

scarcely used at all in the Punjab. The main reason is that value of the increase obtained is higher there, whereas the manures are cheaper than in India. The yield of wheat averages 31·5 bushels in England as compared to 14 in the Punjab.

* The average yield of wheat for some other countries is given below—

	Bushels per acre.
Austria	16
Canada	20
France	16
Germany	18·7
Egypt	15
United States of America ...	12

* McConnell's "Agricultural Note Book."

Statistics by Divisions.

Name of Division.	Districts included.	Population (1911).	Net cultivated area.	Uncultivated. Cultivable.	Uncultivated. Uncultivable, including forests.	Main crops.	Average of 3 years from 1915-16 to 1917-18.
			Acres.	Acres.	Acres.		Acres.
Ambala	Hissar	3,518,632	6,586,880	1,786,855	1,096,984	Gram	2,048,351
	Rohtak					Bajra	1,361,242
	Gurgaon					Wheat	920,003
	Karnal					Jowar	601,975
	Ambala					Barley	519,618
	Simla						
Jullundur	Kangra	3,967,724	4,778,214	1,422,701	5,248,417	Wheat	1,877,457
	Hoshiarpur					Gram	1,318,337
	Jullundur					Maize	538,838
	Ludhiana					Barley	345,181
	Ferozepore						
Lahore	Lahore	4,656,829	4,905,633	1,765,923	1,001,157	Wheat	2,204,458
	Amritsar					Gram	700,087
	Gurdaspur					Rice	393,581
	Sialkot					Cotton	301,333
	Gujranwala						
	Sheikhupura						
Rawalpindi	Gujrat	3,353,052	4,950,428	4,255,303	4,552,252	Wheat	2,238,046
	Shahpur					Bajra	745,099
	Jhelum					Gram	470,624
	Rawalpindi						
	Attock						
	Mianwali						
Multan	Montgomery	3,792,728	5,941,154	9,371,112	2,670,395	Wheat	2,491,531
	Lyallpur					Gram	457,688
	Jhang					*Cotton	418,569
	Multan						
	Muzaffargarh						
	Dera Ghazi Khan						

Note.—Compiled from "Statistics of India-Agricultural."
* Area of cotton is likely to increase considerably in the coming years.

It will be seen that wheat is the main crop in all the divisions. Bajra (*Pennisetum typhoideum*) is important in two divisions, *viz.*, Ambala and Rawalpindi, and is the second most important crop as regards area in the former. Multan, the largest division, has large tracts of culturable waste which will in time be irrigated and bear excellent crops.

Statistics for 5 divisions of the Punjab.

**Table giving percentage of area occupied by various crops in* 1916.

Year 1916-17.

Name of crop.	Unirrigated (lakhs of acres).	Irrigated (lakhs of acres).	Total in lakhs.	Per cent. of cropped area
Wheat	46	49	95	29·9
Gram	42	9	51	16
Barley	8 5	3	11·5	3·6
Juar	12	3	15	4·7
Bajra	27	3	30	9·5
Maize	8	5	13	4·1
Mung, mash, moth ...	5·1	·4	5·5	1·7
Rape (sarson), taramira and mustard (rai).	5	1	6	1·9
Toria	...	4	4	1·2
Sugarcane	·5	3·5	4	1·2
Cotton	2	9	11	3·4
Fodder crops (not shown otherwise).	20·5	20	40·5	12·8
Rice	3	8	11	3·4
Kharif	85	43	128	40·4
Rabi	107	82	189	59·6
Total ...	192	125	317	100

The year 1916-17 represents a good typical year compared to 1914-15 and 1917-18. In a very unfavourable year such as 1918-19, the total cropped area of which was 218·5 lacs of acres, the unirrigated area amounted to 96·5 lacs of acres as compared to 122 for the irrigated area, which remains fairly constant from year

* "Season and Crops Report," Punjab.

to year. In the year 1916-17, which has been taken above, the cotton area is lower than might be expected, the usual area being near 15 lacs of acres. A similar table giving averages from 1914-15 to 1918-19 is as follows * :—

Name of crop.	Unirrigated (lacs of acres).	Irrigated (lacs of acres).	Per cent. irrigated.	Total lacs of acres.	Per cent. of cropped area.
Total area	167·7	120·2	41·7	287·9	100
Wheat	44·7	47·3	51·4	92	31·9
Gram	35·8	8·2	18·6	44	15·2
Barley	7·9	3·8	32·4	11·7	4·0
Juar	8·3	2·2	20·9	10·5	3·6
Bajra	21·2	2·2	9·4	23·4	8·1
Maize	6·8	4·9	41·8	11·7	4·1
Mung, Mash, Moth	4·0	·3	7	4·3	1·4
Rape (sarson) Taramira, Mustard (rai).	5·6	·9	13·8	6·5	2·2
Toria	0·4	3·4	89·4	3·8	1·3
Sugarcane	0·8	3·4	80·9	4·2	1·4
Cotton	2·2	11·0	83·3	13 2	4 5
Fodder crops (not otherwise shown).	16·3	20·2	55·3	36·5	12·6
Rice	2·1	6·5	75·5	8·6	2·9
Kharif	67·4	40·8	37·7	108·2	37·5
Rabi	100·2	79·4	44·2	179 6	62·4

It will be noted that of the total cultivated area over 40 per cent. is irrigated. More than 50 per cent. of the wheat is irrigated and over 80 per cent. of the cotton and sugarcane, whereas only 32 per cent. of barley and less than 20 per cent. of gram is irrigated. The figures for millets and maize are instructive, showing that bajra is best able to do without irrigation, and next to that juar, and then maize. As regards rapeseeds all except toria are "barani" crops, whereas toria is almost entirely irrigated.

Irrigation.—Of the total irrigated area of †12,200,000 acres in 1916-17, 8,600,000 acres were irrigated from canals. The main canals of the

Canals.

* "Season and Crops Report," Punjab.
† Statistics of India, Agricultural.

Province are—

(1) The Western Jumna irrigating 828,000* acres in 1916. The culturable commanded area is 2,315,000 acres.

It takes off from the Jumna at Tajewala and irrigates a tract comprising parts of Ambala, Karnal, Rohtak, and Delhi. It was opened in 1820.

(2) The Sirhind irrigating 1,425,000 acres in 1916 and taking from the Sutlej at Rupar. The culturable area commanded is 3,900,000 acres; it irrigates in the districts of Ludhiana and Ferozepore and in the Native States of Patiala and Jind. The canal was opened in 1883.

(3) The Upper Bari Doab irrigating 1,200,000 acres in 1916 and taking from the Ravi at Madhopur. The culturable commanded area is 1,600,000 acres approximately. It irrigates parts of Gurdaspur, Amritsar, and Lahore. This is the second oldest perennial canal in the Province, having opened in 1860 as compared to 1820 for the Western Jumna Canal.

(4) The five linked canals comprising the Upper and Lower Jhelum taking from the Jhelum at Mangla and Rasul respectively; the Upper and Lower Chenab taking from the Chenab at Marala and Khanki respectively; and the Lower Bari Doab taking from the Ravi at Balloki. The Lower Chenab was finished in 1891, and irrigates the Doab between the Chenab and the Ravi comprisng 2,600,000 acres. The Lower Jhelum was finished in 1902, and irrigates the Doab between the Jhelum and the Chenab comprising a commanded area of 1,160,000 acres. The remaining three belong to what is known as the Triple Project. The Upper Jhelum irrigates a part of the Gujrat District, and delivers its main supply of 10,000 cusecs to the Chenab River above Khanki, the Head Works of the Lower Chenab. The Chenab itself is tapped higher up at Marala, and irrigates portions of Sialkot, Gujranwala, and Lahore, and delivers its main supply of 11,700 cusecs to the Ravi at Balloki, the water being used for the Lower Bari Doab Canal, which commands a tract of 1,637,000 acres, and is designed to irrigate 900,000 acres. Thus since 1915, when the Triple Project was completed, the Lower Chenab is using Jhelum water; whereas most of the supplies of the Lower Bari Doab come from the Chenab river. The total area irrigated by these five linked canals in 1918-19 was †4,468,000 acres. All the above canals are perennial, *i. e.* they run supplies in summer and winter. There remain the inundation canals, which are in the main running in the kharif only.

* Figures for the canals are taken from the Administration Reports of the Punjab Irrigation Department.

† Irrigation Department, Punjab, Administration Report 1918-19.

The latter have no masonry head-works as a rule and no weir, hence they depend for supplies on floods in the rivers.

These inundation canals are found mainly on the Sutlej and along the lower reaches of the Chenab and the Indus. They irrigate a total area of 1,000,000 acres.

Wells.—The figures of 1916-17 show that 3½ million acres were irrigated from wells, and in the district of Sialkot alone 400,000 acres were so irrigated from 30,000 wells, the number of which has since decreased owing to irrigation by the Upper Chenab Canal. Jullundur District also possesses 30,000 wells. The number of wells is estimated at 290,000.* Water is generallylifted by means of a wooden Persian wheel. In the south-east, in the districts of Gurgaon, Delhi, Rohtak, Lndhiana, etc., the *charsa* or leather-mote is also extensively used. The self-delivering charsa called "sundhio," which is so common for lifts up to 30 feet in Western India, is practically unknown in the Punjab. Recently iron Persian wheels have been introduced in Ludhiana and Delhi, and were rapidly extending before the war. Very few have been put up since 1914. The capital value of a well 30 feet deep is estimated at Rs. 750.

Sailab land.—In addition to canal and well irrigation a small area is flooded by the rivers annually when in flood. This land is sown after the river recedes, and receives as a rule very little preliminary cultivation.

New Canal Projects.—The following are the most important new projects expected to be sanctioned and proceeded with shortly, *viz.* :—

(*a*) The Sutlej Dam, (*b*) the Sutlej Valley, (*c*) the Sindh Sagar Doab, (*d*) the Haveli, and (*e*) the Woolar Lake projects.

(*a*) and (*b*) The Sutlej Dam and Sutlej Valley projects are inter-connected, and will derive supplies from the Sutlej, which will ultimately have a larger dam at Bhakhra and 4 weirs. These two projects will between them command an area of 6 million acres and improve the supplies of the present Western Jumna and Sirhind Canals. Besides irrigating tracts very liable to famine in British territory, these projects are intended to irrigate large areas in Bahawalpur and Bikaner as well. These canals when completed will have very large kharif supplies as compared to Rabi supplies.

* Season and Crops Report, Punjab.

(*c*) The Sind Sagar or Thal Project will irrigate the large tract between the Indus and Jhelum rivers south of the Salt Range, and will command an area of over 2,000,000 acres.

(*d*) The Haveli Project is in the main designed to safeguard the existing irrigation from inundation canals on the Chenab, particularly the Sidhnai Canal. It is designed to increase existing irrigation by over 350,000 acres.

(*e*) The Woolar Lake Project contemplates a dam on the Jhelum River in Kashmir, and is designed to supplement the Rabi supplies of the five linked canals, *viz.* the Upper and Lower Jhelum, the Upper and Lower Chenab, and the Lower Bari Doab.

Administrative arrangements.—The province is divided into twenty-nine districts, which in fertile tracts generally measure from 1½ to 2 million acres. The district is in charge of a Deputy Commissioner, whose main work is in connection with land revenue collection and settling of revenue disputes. Each district is divided into 3 or 4 tahsils under a tahsildar. A tahsil is divided further into zails, each of which has one kanungo and 20 or 30 patwaris. A zaildar, who is a non official, helps in the work of running a zail. A patwari has generally one or two villages in his charge. Each village has a headman or lambardar, who is generally the most influential man in the place. The lambardar assists in the collection of revenue and is a semi-official. The Deputy Commissioner is subordinate to the Commissioner of the division, who has generally six districts in his charge. There are five divisions in the province, each of which is fairly distinct agriculturally (see page 6). While as regards area and total cultivation the Punjab is comparable to the United Kingdom, it differs enormously from it in many important aspects. The total budget of Britain was 1,400 crores in the year 1920 as compared to 7 crores only for the Punjab. Out of the total revenue of the province * 4½ crores is derived from land revenue, and farming is practically the only industry of the Province. Perennially irrigated land sells in the Punjab at nearly 600 rupees per acre, which is higher than what good land sells at in Britain. If we take the cultivated area as 30 million acres, and value it at Rs. 200 per acre only, we get the figure 6,000 crores as a rough estimate of the capital value of the agricultural land of the Punjab.

The canals with a nominal capital value of 24 crores † are administered by the Irrigation Department, whose annual budget

* "Statistics of India, Agricultural", 1917-18.
† Irrigation Department, Punjab, Administration Report, 1918-19.

for running expenses is about one crore. Though only a very low charge is made for water rate and land revenue, the return per annum is 13 per cent. (average of 5 years up to 1918-19) on the capital cost of the canals after paying all running charges. There is still a vast field for extension of irrigation in the province, and this combined with the harnessing of water power in the Himalayas and the utilisation of oil from the Attock Oil Field, combined with improvement in agricultural practice, means untold wealth and prosperity for the future.

The Agricultural Department, inaugurated in 1905 only is still in its infancy, and, together with the Veterinary Department, has only a budget of 10 lakhs. Proposals for extension and strengthening of the staff of the Agricultural College at Lyallpur are being favourably considered by the Local Government, and, if carried through, will multiply the efficiency of the department and more than treble its utility in the province in the near future.

CHAPTER II.—PHYSIOLOGY OF PLANTS.

Introductory.

The farmer's method of production is by the growing of certain plants, parts of which, such as fruit, stem, leaf or root, as the case may be, represent his saleable commodity. The rearing and maintaining or fattening of animals and poultry is another part of his business, but this aspect is of comparatively minor importance in most parts of the Punjab. Animal husbandry itself represents but an elaboration of some of the farm products. The growing of plants of some sort is therefore the most essential part of agriculture; hence some knowledge of the requirements and life processes of plants is an essential part of Agricultural Science.

Essential parts of plants.*

The parts of a plant which are essential to its life are the roots, stems and leaves. The most important function of the roots is the absorption of water and certain food substances from the soil. This water is conducted through the stems into the leaves, where most of it is transpired into the air.

Absorption of water and salts from the soil.

The roots take water and dissolved food through the root hairs. The latter are unicellular structures found just behind the growing tips of the finest rootlets. They can be seen on the roots of seedlings germinated on moist blotting paper or loose sand. If a plant is pulled up by the roots from a soil, the root-hairs, being fragile, are destroyed, but they can be seen by the naked eye if the surrounding earth is washed away carefully. The root-hairs are closed elongated tubes; water and food passes in through the walls by a process known as "osmosis". This process may be illustrated by the following experiment:—

Take an egg and remove the outer hard shell, leaving the inner skin or membrane, which encloses the yolk and white, intact. This can easily be done if the egg is put in weak acid, *e. g.* vinegar or hydrochloric : for some time beforehand. Now place the soft egg in a strong solution of common salt, this will cause it to shrink, but on being taken out and put in pure water again it expands. The shrinking or swelling was due to water passing out

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* "Feeding of Crops and Stock"—Hall (published by John Murray, London, pp. 1—[illegible]).
"Agricultural Botany"—Percival (published by Duckworth, London, pp. 177—240).
"Strasburger's Botany" (published by Macmillan, London, section II, pp. 171—323).

or into the egg according as to whether the solution in contact with it was stronger or weaker than that in the egg itself. A root-hair acts in exactly a similar manner. The solution of cell-sap in the root-hair being more concentrated than soil water, the latter flows into the root-hair. As the root-hairs are in contact with neighbouring cells of the root, the process is continued. The solution from the root-hair passes to neighbouring cells, which have more concentrated solution in them, and hence the process is continuous. If the root-hairs were not in contact with other cells, the continued passage of soil solution into them would dilute the cell-sap until it was of the same concentration as soil water when further movement would cease. Should the soil solution become more concentrated than that of the cell-sap, the latter would shrink and the plants wither. This is the explanation of what happens in "kallar" or salty soils, and is also the reason why in such soils more frequent waterings are necessary to keep the concentration of the soil solution down.

Protoplasm and root-hair cell.

The wall of the cell of the root-hair is lined with a living membrane called "protoplasm". This substance further affects the process of absorption in the root-hair as compared to the egg membrane, and seems to exert a selective action so that the amount of the different substances absorbed is not in the same proportion as they exist in the soil solution.

Necessity for plant food to be in solution.

The root-hairs can only absorb substances already in solution in the soil water. This fact is of great importance, and, as will be seen later, underlies much of our agricultural practice. Solid food can only be taken in a soluble state.

Chemical elements in plant food.

The essential chemical elements which the plant obtains from the soil are Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sulphur, Iron, Hydrogen and Oxygen. Others not essential for healthy growth, but still absorbed in considerable quantities, and probably useful, are Silicon and Chlorine. Of the nine essential elements Nitrogen, and to a less extent Phosphorus and Potassium, are most important in that considerable quantities are taken, and the supply of these is apt to be short in the soil. Practically all soils contain sufficient of the other essential elements. These three elements are the only ones it is necessary to add in manures, though lime is sometimes indirectly useful. The relative importance of Nitrogen, Phosphorus and Potassium can be demonstrated by growing seedlings in solution, from which one or other of them is lacking. For such an experiment the water and salts

must be pure. Instructions for preparation of water cultures of this kind can be had in most Agricultural Chemistry Text Books.

Roots must feed over a large area.

The percentage of the food substances actually dissolved in the soil water is small, so that plants have to absorb large quantities of water Water moves downwards in the soil fairly rapidly by gravity, but the upward movement by surface tension is comparatively slow. The roots can only take water in contact with them, and hence th deeper and more spreading they are, the larger the mass of water they are in contact with. This partly explains the benefit of delaying the first watering after sowing so as to encourage the roots to go down. Further, one can see there is no advantage in having more than a certain number of plants on the ground, *i.e.* sufficient for the roots to make full use of the soil.

Form in which plants take nitrogen, etc.

As pointed out, plant food in the soil can only be absorbed if in solution. Nitrogen and Phosphorus can only be absorbed in the form of soluble salts as nitrates and phosphates of Potassium, Sodium or Calcium. Potash may apparently be absorbed in the form of any soluble salts.

Vascular tissue.

The very dilute solution of salts in soil water is thus absorbed by the root-hairs by "osmosis" controlled by the living matter (protoplasm) in the cells. By a similar process it passes on to adjoining cells of the root until it reaches the woody part of the root. This woody part consists of long tubular vessels. Apart from its function of giving mechanical support, its main purpose is for the conduct of the solution absorbed by the roots up to the leaves of the plant. The mechanism of this passage is not understood, and still awaits a scientific explanation. In the case of some tropical trees the water is thus raised two or three hundred feet. There is no doubt the solution is carried up, as can be proved by simple experiments.*

Bast.

Around the wood in such plants as cotton is another structure similar to above called "bast." Its function is to conduct food material manufactured in the leaves to all other parts of the plant where growth is proceeding, or where food is being stored.

Structure of the leaves.

The whole of the carbon which forms the food of the plant is manufactured into compounds soluble and otherwise in the leaves. The latter

* See Percival's "Agricultural Botany," page 190.

posses veins which are visible in most leaves. These veins consist of wood and bast cells which connect through the leaf-stalk with the wood and bast cells of the stem. The raw materials, water and salts, reach the leaf through the wood cells, and the manufactured material passes where required through the bast cells.

Stomata.

The leaf has a further structure called "stomata," which communicate with the air, and through which the plant obtains Oxygen and carbon dioxide. This latter substance, though present in the air to the extent of four parts in ten thousand only, is practically the sole source of carbon for the plant.

Assimilation.

The main function of the leaves is assimilation of carbon dioxide, its breaking up and elaboration into compounds suitable for the building of the plant. This process of assimilation is carried on by the green matter in the leaves, and can only take place in presence of light. All green parts of plants have this power, which is not possessed by animals, or even by many plants, *e.g.*, mushrooms and most fungoid pests such as "broom-rape" of tobacco. If it were not for this power possessed by the green matter (chlorophyll) of plants, all life would cease in a comparatively short time. The function is therefore a very vital and important one.

Food manufactured in the leaves.

The foods manufactured in the leaves are of two classes, *viz.* (*a*) carbohydrates and (*b*) proteins. The former consist of Carbon, Hydrogen and Oxygen, *e.g.*, sugar and starch. The green colouring matter in the leaves has the power under the influence of sunlight of combining water (consisting of Hydrogen and Oxygen) with carbon dioxide gas to form carbohydrates with the liberation of some of the Oxygen. The energy required for this is obtained from sunlight. If two seedlings are grown under exactly similar conditions except that one is in darkness and the other in the light, it will be seen that the former develops no green matter, and growth ceases as soon as the food material in the seed is exhausted. The formation of starch in the leaves and the necessity of light and air for this purpose can be shown by simple experiments.*

Proteins.

Proteins are a class of compounds consisting essentially of Carbon, Oxygen, Hydrogen and Nitrogen together with small quantities of Sulphur and Phosphorus. They are the most important substances in

* See Hall's "Feeding of Crops and Stock."

the composition of animals and plants. The flesh and blood of animals and the protoplasm of plants consist mainly of proteins. Very little is known of the manner or place of their formation. It is believed that the early stages of their formation take place in the leaves by a combination of carbohydrates and the nitrates and mineral salts absorbed from the soil. The later stages would appear to occur in all living cells of the plant. It seems that potash and calcium play an essential part in the process by some form of catalytic action, though these substances form no part of the finished product.

Storage of food.

The food manufactured in the leaves is either passed through the bast to parts of the plant which are growing, and thus helps to form new cells, or it may be stored in various parts of the plant. Examples of such storage are seen in case of fruits or seeds of all plants and in the swollen stems or roots of such plants, as turnips, carrots, bulbs of onion, or tubers of potatoes or sweet potatoes.

Transpiration.

As pointed out above, the mineral solution taken by the roots is very dilute. It is concentrated in the plant by the evaporation which takes place through the stomata of the leaves. The latter are mainly found on the lower sides of the leaf. The plant thus transpires several hundred pounds of water for each pound of dry matter produced. The transpiration is regulated by the stomata, which close if the transpiration is greater than the supply from the roots. Some plants have special means of checking transpiration, *e.g.*, small hairs on the leaf as in case of gram and lentils. "Wan" (*Salvadora oleoides*), which grows in dry desert land, has very thick small leaves, and "karil" (*Capparis aphylla*) is a desert plant still further adapted for minimum transpiration. Both the above trees are common in dry unirrigated tracts in the Punjab plains. Some trees check transpiration by casting their leaves. In the warm summer season plants during the middle of the day often assume a wilted appearance, even though the soil be thoroughly moist, owing to the roots not being able to take up water as fast as it is transpired. Such temporary wilting will not cause leaves to drop. If the soil is dry, however, the plant may drop some leaves to save itself. After severe frost also the roots may be unable to act until the ground has thawed, while the upper air may be warm and transpiration proceeding. Normally the leaves transpire, as much as the roots absorb less the quantity retained by the growing plant, which is considerable, and varies from 80 to 90 per cent. or more of its green weight.

Respiration.

Breathing is as necessary to plants as to animals, though in the former the process is masked during daylight by the splitting up of carbon dioxide gas and freeing of Oxygen. At night, however, only breathing can take place. If we take a water weed and put it in a test tube full of water, and invert the latter over a basin of water in daylight, we find bubbles soon collect at the top of the tube. This gas will cause a glowing taper to burst into flame, and is mostly Oxygen. The carbonic acid gas taken from the water has been split up in the formation of carbohydrates by the plant and some Oxygen set free. If the experiment is repeated in the dark, gas collects slowly, and on testing will be found to turn lime water milky, and is in fact mainly carbon dioxide.

Respiration in plants takes place all over the growing parts, including the roots. In the latter the "root-hairs" and growing tips of roots only take in air, and hence for healthy growth the roots must be in ærated soil. Fortunately very little air is required, and sufficient is present in all normal soils. When water stagnates in the soil, however, or when a crust forms after rain, the entry and movement of air is interfered with and the plant suffers. This is one reason why the maintenance of "tilth" and breaking of the "karand" or "papri" which forms on the surface after rain or irrigation is important: this is realized in practice by most zemindars. The importance of "anhi godi" (blind hoeing) for sugarcane before the shoots are above ground is largely connected with this factor. The æration of the soil in case of young rapidly growing plants is very important. It may be noted that ripe seed respires, as the young embryo cannot otherwise live. The germination of old seed is probably defective, because part of the food store has been exhausted in this way.

Reproduction.

We have now described the ordinary life processes of the growing plant which consist in absorbing water and mineral matter from the soil, assimilation of carbon dioxide and formation of carbohydrates and proteins, and the burning up of a small part of the former in respiration. When the plant has made sufficient vegetative growth the process of reproduction starts, and continues along with the vegetative growth. In plants reproduction may be (*a*) vegetative or (*b*) sexual. The process of vegetative reproduction may be illustrated in the case of potatoes, where under-ground tubers become enlarged and each eye-bud can give rise to a separate plant when replanted. Sweet potatoes are reproduced by planting the stems. Sugarcane, which never flowers in th

Punjab, depends entirely on vegetative reproduction. Several grasses, *e.g.*, Dub, Baru, etc., reproduce themselves mainly in this way also. Similarly onions and "turmeric" form bulbs for reproductive purposes. Gardeners reproduce roses and many other garden plants in this way. In vegetative reproduction we are merely expanding or splitting up the parent plant into a number of exactly similar ones. This is very different from the sexual reproduction of animals and plants. In the latter one cell after fertilization by another cell, often derived from another individual, gives rise to a new animal or plant which may be distinctly different from one or both of its parents. If a flower be carefully examined, it will usually be found to contain inside the coloured petals a central female portion surrounded by many male portions. The female portion "pistil" contains one or more egg-cells, which are formed in a similar way and serve a similar purpose to the egg-cells of a female animal. On the upper part of the pistil will be found a surface ("stigma") designed for the reception of the dust (or "pollen" grains) formed in the male organs (anthers). When one of these pollen grains from the male portion of a flower falls on to this stigma, a tube is formed which grows down into the pistil and fertilizes the ovule or "egg" in the female part of the flower. This tube can only be seen with a microscope. In some flowers the pollen always, or almost always, comes from the male part of the same flower, *e.g.*, wheat; in others, such as cotton and taramira (*Eruca sativa*), pollen grains in a considerable proportion at any rate, come from other flowers or plants. The flowers of many plants are so constructed as to ensure the certainty or probability of the pollen coming from another flower. In many cases such provision is made by the stigma and anthers on the same flower regularly ripening at slightly different times. In other plants, such as the date-palm, the flowers of any particular tree contain only the female or the male portion of the flower, as the case may be. When the pollen comes on to the stigma from the same flower, it is called self-fertilization; if from another flower, cross-fertilization. The transference of the pollen from one flower to another in cross-fertilization may be merely due to its falling or being blown by wind; but it is often carried by insects, and in many flowers honey is produced, which attracts insects.

The ovule or egg-cell in the female portion of the seed is contained in a skin which eventually becomes the seed-coat. After fertilization this seed coat swells and the fertilized egg-cell develops into the very small young plant (embryo) which

can be found in any seed. The last stage of the development of the seed consists in the storage in it of the food material for use in germination, and, lastly, the drying up with a diminution in thickness of the seed-coat. This food material may be stored in the two first formed leaves (cotyledons), which are then more or less thickened, as in the case of gram and turnip, toria, etc.

These leaves may (as in gram) remain in the seed after germination, functioning merely as food stores, or they may be brought above the surface and function for a time like ordinary leaves (*e.g.* turnip.)

The food in the seed, wherever it may be stored, consists of proteins, carbohydrates and fat. Protein is always present in considerable proportions, forming more than 10 per cent. of wheat and barley grains, and nearly 20 per cent. of gram and cotton seeds. The proportions of carbohydrate and oil, however, vary greatly in different seeds. Thus in wheat or barley there is only 1 per cent. or 2 per cent of oil and 66 per cent. of carbohydrates, whereas cotton seed contains about 20 per cent. of oil and only some 15 per cent. of carbohydrates. A point of some importance to the farmer is the fact that a large amount of the Nitrogen and Phosphorus absorbed from the soil is eventually transferred to the seed, whereas much of the Potash taken from the soil remains in the leaves and stem of the plant. Thus by the sale from the farm of the seed of crops such as wheat and oil-seeds, whilst retaining the remainder of the plant, we are parting with much of the phosphorus taken from the soil by the crop, but are not losing much of the potash. Conversely the manure from animals receiving large quantities of cotton seed aud gram is much richer in Nitrogen and Phosphorus than that from animals not so well fed. This is another of the reasons why phosphorus manures are more likely to be needed than potash salts in the course of ordinary farming where the stems and leaves of the plants are not sold. For the same reason the ashes of wood, cotton sticks, etc., must be regarded mainly as potash manures.

It has been shown that the seed consists of the seed-coat, the young plant (embryo), and a food store. One or more of these seeds is enclosed in the female part of the flower, which, when ripe, is spoken of as the fruit of the plant. The boll of cotton plant, the pods of gram or toria are examples of fruits in which this structure can be plainly seen. When the fruit dries up, it either breaks open and liberates the seeds, or the whole fruit falls off the plant containing the seed within it. The

cotton plant affords an example of the former method; the wheat grain which falls out off the straw of the wheat is really a fruit enclosing one single seed; and oranges and melons are examples of fruits containing several seeds. The so-called "seed" of the beet-root is also really a fruit containing several seeds, as is easily seen if one is cut or broken up.

In nature these seeds or fruits are spread about more or less widely by various agencies, of which animals, birds, and the wind are the commonest. The seeds or fruits of many plants are very obviously and specially adapted for being carried by the wind, or becoming attached to passing animals, or to be attractive food to animals or birds. The seeds of Poli (*Carthamus oxycantha*), the seeds of the grass called "Kutta" (*Cenchrus echinatus*), and the edible grains and fruits respectively afford examples of these three different adaptations for dispersal.

With wild plants only so many of the seeds will germinate as happen to meet with the right conditions. But when a farmer is growing a crop he has to meet the expenses of rent and cultivation of the whole of his field. If his farming is to be profitable, he must sow his seed so that they will germinate in every part of his field. This means that he must sow the seeds everywhere under such conditions as are necessary for bringing them to active growth, or, in other words, for germination.

Changes during germination.

The "embryo" in the seed after it is sown exists and develops for a time on the store of food material stored in the seed. The seed-coat has first to be moistened and softened. Some seed-coats are so hard that artificial methods have to be used to accelerate the process, *e g.*, Java Indigo in Behar is treated with weak acid before sowing. After the seed-coat is moistened, the food material ferments and becomes soluble and available for the swelling embryo. All this requires moisture, and hence water is the first necessity for germination.

Necessity for moisture and right temperature.

There is a definite range of temperature for the germination of any particular seed. Rabi crops will generally not germinate in the hot season, whereas kharif crops will not germinate in the rabi season. This is a useful provision of nature, as it prevents waste through the seed germinating at the wrong time of the year, and the young plant subsequently dying owing to adverse weather conditions. Some seeds will not germinate after they are ripe until they have been exposed to certain changes by storing or in nature even

though moistened and kept at a suitable temperature, *e.g.*, lucerne and clover*.

Most seeds, however, will germinate as soon as moistened if kept at the right temperature and with fairly free access to air. Air or Oxygen is the third essential condition for successful germination. Air is required for the respiration of the actively growing seed and also to facilitate the change of food material into a soluble condition. Small seeds are very sensitive in this respect and if planted too deep often fail to start germinating. Once germination starts the young shoot can generally force its way through to the surface, so that failure to germinate is not due to mechanical causes so much as to insufficiency of air supply.

Importance of air.

The essential conditions for germination can be demonstrated by simple experiments quoted in various text-books. Light is not necessary for germination. In practice the necessary conditions for germination are provided by sowing at the right season in moist fine earth which is sufficiently pressed down so that the seed is in close contact with it. The seed must not be sown too deep, and the surface of the soil must not be allowed to get caked.

In the germination of the seed the softening and swelling of the seed coat is most prominent at the point where the root emerges (the micropyle). The root on emerging into moist soil soon develops root-hairs and small branches, and firmly anchors itself in the soil. Water is absorbed by the root-hairs to meet the need of the rapidly growing plant. By the growing and lengthening of the young stem the young plant (plumule) emerges, and on reaching the light develops green matter, and is adapted for manufacturing its own food, and is therefore established in life.

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* "Botany for Agricultural Students"—Martin, page 68.

CHAPTER III.—CHEMISTRY OF THE SOIL.

The soils of the Punjab plains are of alluvial origin, *i.e.*, deposited from water. They are coarse or fine according as the current from which they were deposited was flowing fast or slow. While the soils are, generally speaking, very uniform, considerable variation occurs even in different parts of the same field. The particles of which soil is composed vary in diameter from 1 mm. in the case of coarse sand to less than ·005 mm. in case of clay. Fine sand and silt occupy intermediate positions between the above. The area of the particles in one cubic foot of ordinary light loam is about one acre, and even in coarse soils the area of the surface of the particles is ¼ acre or 11,000 square feet. This large surface is being constantly exposed to the weathering influences of water and air as well as to that of chemical substances such as carbon dioxide, etc.. A cubic foot of dry soil weighs from 80 to 110 lbs., depending mainly on whether the soil is mostly clay or sand. An average soil may be taken to weigh 92 lbs. per cubic foot. The top nine inches of an average soil will therefore weigh about 3 million lbs. per acre. A comparatively small proportion of this mass consists of plant food, as will be seen from a study of the analysis given below.

Plant Food in the Soil.

Eight analyses of soils at Lyallpur by the Chemical Section. Figures are percentages of "air dry soil" containing ·5 to ·7 per cent. of water. Samples are of top 9 inches of soil. Available = soluble in 2 per cent. Citric Acid. Total = total soluble in strong HCL (Hydrochloric acid).

	Loss on ignition (organic matter).	N_2	Total P_2O_5	Total K_2O	Ca O	Available P_2O_5	Available K_2O	Carbonates as $CaCo_3$
Highest ...	3·52	·052	·21	1·30	3·22	·074	·029	4·27
Lowest ...	2·75	·026	·14	·76	·82	·012	·009	1·30
Average ...	3·13	·041	·16	1·06	1·67	·042	·022	2·51
or in round figures ...	3	·04	·15	1	1·5	·04	·02	2·5
Per acre lbs. in top 9 inches.	90,000	1,200	4,500	30,000	45,000	1,200	600	75,000
Per acre lbs. in tons.	40	½	2	13	20	½	¼	33½
Soil of square 26 S. end.	3·30	·04	·16	1·3	·8	·05	03	1·60
Tons per acre ...	44·2	·54	2·14	17·4	10·7	·7	·4	21·4

Supplied by Mr. Wilsdon, Agricultural Chemist.

It will be seen that soil of square 26 is very nearly equal to the average, and will therefore be taken as a basis for further discussion.

We may compare with the above analysis made of English soils, *e.g.*, Hall's Survey of Surrey, Sussex, and Kent soils and of two plots at Rothamsted (A) and (B), which are parts of the Broadbalk field, (A) has not been manured for 50 years, and now gives an average of 10 maunds of wheat annually, and (B) is from the same field, but manured annually with 14 tons of farmyard manure, and yields 30 maunds of wheat annually on the average. The method of analysis is the same as at Lyallpur, except that 1 per cent. Citric acid is used instead of 2 per cent. as at Lyallpur.

	Loss on ignition (organic matter).	N_2	Total P_2O_5	Total K_2O	Ca O	Available P_2O_5	Available K_2O	Carbonates as Ca Co_3
*A ...	4·20	·10	·114	·274	2·48	·008	·003	2·71
B ...	6·76	·22	·215	·430	2·68	·056	·038	2·92
5 fertile Thanet soils—								
Highest ...	6·58	·22	·282	·57	1·79	·119	·04	2·00
Lowest ...	2·95	·10	·084	·22	·18	·019	0·14	·02
Average ...	5 01	·185	·169	·404	·91	0·48	·020	·63

The most striking differences are to be found in the columns under organic matter and Nitrogen. In the latter, especially the percentage in Punjab soils, is low as compared to English soils. The supply of potash in Punjab soils seems to be abundant. In other respects the soils are similar, at any rate as far as chemical composition goes.

Physical analysis.—Besides a chemical analysis the chemist generally examines the soils physically by dividing it into several classes of particles of varying size. This is generally done by shaking with water according to a standard method. In this way the proportion of sand, fine sand, silt, clay, etc., in any particular soil is determined. It must be admitted, however, that even with a double analysis of this kind very little can be definitely said as to the fertility or otherwise, of a soil. Of course, harmful substances, such as an excess of salts, can be thus detected. If the person analysing the soil has experience of the agricultural properties of land in the neighbourhood, he can then form a much better judgment of the fertility than if he relied on analysis

alone. This is the reason "soil surveys" are so important, and also why the first survey should be done in a cultivated region to form a basis. When a good start has been made it should be possible to classify with great accuracy hitherto unbroken land. Such a survey should be an essential feature of all canal projects, and would be a very cheap insurance against costly mistakes.

Plant food removed by crops.—As pointed out in a previous chapter, the food constituents which are generally deficient for the needs of the plant are Nitrogen, Phosphorus and Potash. The amount of these removed by some of the important crops are given below :—

		Nitrogen.	Phosphoric Acid.	Potash.
		lbs.	lbs.	lbs.
WHEAT ...	15 maunds grain ...	19·68	11·52	4·24
	30 maunds bhusa ...	14·74	3·16	17·76
	Total ...	34·44	14·68	22·00
MAIZE ...	20 maunds grain ...	25·92	11·13	8·96
	25 maunds fodder ...	12·81	7·98	22·89
	Total ...	38·73	19·11	31·85
SUGARCANE ...	10 tons stripped cane ...	10·8	10·4	12·2
	6 tons leaves and tops ...	17·3	4·9	12·1
	Total ...	28·1	[illegible]	24·3
COTTON ..	150 lbs. lint ...	·32	·12	1·00
	290 lbs. seed ...	9·50	3·44	3·34
	5,000 lbs. stalks ...	127·50	50·00	90·50
	Total ...	137·32	53·56	94·84

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Notes.—The wheat analysis is by Leather, Agric. Ledger, Vol. X, pages 151 and 154. Maize from "Southern Field Crops," page 271. The percentage of Nitrogen is the same as given by Leather. The figures for cotton are partly from Morgan's "*Field crops for the Cotton Belt*," page 82, and partly based on weighments of stalks at Lyallpur. The weight of stalks given in American books is generally much smaller than above.

In the case of wheat and maize it may be noted that most of the Potash is taken in the straw, whereas Nitrogen and phosphoric acid are mainly in the grain. Taking Nitrogen alone, itwll be seen, on comparing with the soil analysis given before, that there is enough Nitrogen for nearly forty crops even in Punjab soils, and much more in English soils. Similarly of available phosphoric acid there is enough for 80 crops of wheat. This represents the amount in the top nine inches only of soil and we have learnt elsewhere that plants send their roots severa feet down. This being the case, the question occurs, why is i that soils respond so well to manuring ? and why does such small dressings of manure, which often only increase the Nitrogen of the soil by from one to three per cent., result in such increase of yields ? The answer is apparently that the plant food in manures is very easily available, and the quantity given, though only a small proportion of the total in the soil, is generally more than one crop takes.

Farmyard manure.—This is the term applied to the ordinary rubbish collected near the steading consisting of droppings of cattle, waste straw, ashes from the fire, etc.* This is almost the only form of manure known in the Punjab, though in various parts of the country other material is occasionally used. The comparison of farmyard manure in the Punjab and in England may be seen by studying the analysis below :—

	F. Y. M. at Lyallpur analysed by Wilsdon.	Lbs. per ton.
Water ...	70 per cent.	
Loss on ignition ...	15 „	
Ash ...	15 „	
Total nitrogen ...	·4 „	9
Total P_2O_5 ...	·25 „	6
Total K_2O ...	·15 „	8½
Available P_2O_5 ...	·13 „	3
Available K_2O ...	·13 „	3

Compare with this McConnell's figures based on analysis by Voelker, which give averages of home F.Y.M. as containing—

Nitrogen ...	9—15	lbs. per ton.
Phosphorus ...	4—9	„ „
Potash ...	9—15	„ „

* See "Manures in the Punjab" by W. Roberts.

The reason why potash is low in India is probably because very little, if any, bedding is used here. Bullock dung is the basis of farmyard manure, and as that is used largely as fuel, the supply of manure is limited. The crops generally manured in the Punjab are vegetables of all kinds, melons, maize, and sometimes cotton and wheat. Sugarcane is generally manured indirectly, as it follows maize which has been heavily manured.

Farmyard manure deteriorates rapidly if exposed too much It should therefore be stored in pits, or at any rate in the shade, where it will not be constantly exposed to sun and dry winds. A cheap earthen pit can be made by everyone, and if this is done, there is a chance of collecting leaves and other rubbish which otherwise goes to waste.

Another manure that is largely wasted in India is "night-soil". In Japan and China this manure is regarded as invaluable, and largely accounts for the intensive and high system of farming possible in those countries.

Artificial manures.—Those whose function is to supply potash have not given any indication of their value in tests so far conducted. The same may be said largely as regards phosphatic manures such as bone meal. Experiments at Lyallpur have not shown any definite positive benefit from the use of these, though it is possible, if not probable, that their use would extend once nitrogenous manures become used.* Positive results have followed the use of nitrogenous manures in almost all cases. Their use is not, however, justified under present conditions, as the value of the increase is generally not equal to the high cost of the manure. With cheap electric power it may before long be possible to have nitrogen manure manufactured in the Punjab, and if it could be turned out at from Rs. 8 to Rs. 10 per maund, there should be a great future for it as a manure for wheat and cotton.

The question is often asked why artificials are used in England, but not in India. The reason is that the value of the increase obtained in the former is greater than in the latter, and also the cost of the manure is less.

Nitrogen fixation.—The soil has two natural sources for the replenishment of its nitrogen supply, both of which depend on the action of organisms known as "bacteria." In the first place it has been known for over half a century that plants of the

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* See *resumé* of manurial experiments at Lyallpur by Mr. Faulkner.

"leguminosæ" order almost invariably have colonies of bacteria living on their roots which fix Nitrogen from the air, and thus render it ultimately available to the crops. The roots of plants like gram, peas, guara, etc., if examined during growth will be found to have excrescenses, warts, or nodules sometimes as large as a rupee. These nodules are made by bacteria, and their presence is very beneficial both to the parent leguminous plant and to the subsequent crop, which benefits from the nitrogen fixed during the life of the leguminous crop. The second source of gain of nitrogen is from the action of bacteria living in the soil independent of crops. All healthy fertile soils have a large number of different kinds of bacteria living on the organic matter in the soil. Some of these add considerable quantities of nitrogen to the soil by fixing it from the air and forming compounds which ultimately are transformed into nitrates for the use of plants. The factors controlling this fixation are not well understood, but it would appear the process is very active in the summer, and more so in dry years than in wet years. This latter point requires further investigation. It is known that in wet or water-logged soils the opposite process, *viz.*, denitrification, is active. The figures given below show results of two cases studied by Mr. Wilsdon.

	Fallow.		Green manure experiment.	
	May.	October.	May.	October.
1.	Nitrogen. ·0362 per cent. ...	Nitrogen. ·0375 per cent.	Nitrogen. ·0314 per cent.	Nitrogen. ·0331 per cent.
	1,086 lbs. per acre	1,125	942	993
	Addition = 39 lbs. per acre		= 51 lbs. per acre.	
2.	·0251 ...	·1282	·0226	·0262
	753 lbs. ...	846	678	786
	Addition = 93 lbs. per acre		= 108 lbs. per acre.	

It will be seen that in one case the addition is more than twice the other. Even the lowest figure of 39 lbs. is equivalent to the total nitrogen content of a crop of guara weighing 240 maunds per acre when cut. If this crop were ploughed into the soil instead of being cut and used elsewhere, the addition to the soil nitrogen is about 40 lbs. per acre only. Nitrogen fixation

appears to be much more active in the Punjab than in Britain. This probably accounts for the remarkable fertility of some of the soils of the Punjab though receiving no manure. The treatment of the soil during fallow must have a very marked effect on the fixation process, but as so little is known of the controlling factors, very little can be said at present.

Green manuring.—The growing and ploughing in of a crop to serve as manure for the succeeding crop has been practised on a small scale from ancient times in India. The crops generally used are leguminous, and sann-hemp (*Crotalaria juncea*) has generally been the favourite. Of recent years "guara" (*Cyamopsis psoralioides*) has been found to give much better results at Lyallpur. Green manuring can only be recommended where the summer water supply, whether from rain or canals, is plentiful. (See chapters on crops). The value of green manure does not depend on nitrogen addition alone, but also on addition of organic matter generally so deficient in Punjab soils.

Form in which plant food is available.—This matter has been briefly dealt with in Chapter II. It is only necessary to emphasise in the case of nitrogen that plants are almost invariably able to take this element in the form of nitrates only. The change from complicated organic compounds into nitrates is mainly carried out by bacteria. These are quite distinct from the bacteria referred to above as effecting fixation of nitrogen in the soil. Good cultivation facilitates the process of nitrifying, whereas under unfavourable conditions, such as with water-logging or poor cultivation, the process is hindered, or in some cases the reverse, *viz.* denitrifying, takes place.

CHAPTER IV.—PHYSICAL NATURE OF THE SOIL AND CULTIVATION.

Importance of tilth.

The ability of a soil to yield good crops depends very largely on its physical condition or tilth. This must be distinguished from the "physical nature" of the soil which generally depends on the proportion of sand and clay in it. Other factors controlling the yield, such as "plant food" and water, are affected by the tilth, and hence this matter is of great importance. It cannot be said that we know definitely what constitutes good tilth, nor have we any means of measuring the property exactly. We do know, however, what influences the physical condition beneficially or deleteriously.

Definition.

It is probable that an essential feature of a soil in good physical condition is that it is in what is termed a "crumb" condition.* This means that the individual particles of which it is composed are largely aggregated together. This aggregation enables the soil to hold more water, and leaves more surface for the root hairs of the plants to spread over as well as allowing bigger spaces for storage and movement of air in the soil. The latter is now regarded as an essential condition of fertility.

Whatever constitutes good tilth, there is no doubt about its immense importance, and good crops of high quality cannot be obtained in a soil in poor tilth even if large quantities of plant food are added in the form of manures and the water supply is abundant. On the other hand, a good crop can be obtained from a soil in good tilth without any manuring and with a minimum amount of water.

Distinction between texture and tilth.

The physical nature of the soil or its "texture," depending, as it does, on the proportion of stones, gravel, sand, silt and clay in it, is permanent, and cannot be varied appreciably by ordinary farming practice. These physical constituents can be separated in the laboratory, and will be found to be constant for any particular soil whatever processes of cultivation are employed. The physical condition of the soil or its "tilth" depends, however, on the way in which these particles are arranged. Tilth is thus a temporary condition and is liable

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* King's "Physics of Agriculture," page 108.

† Howard, "Pusa Bulletin" No. 61 of 1916.

to be affected by every influence acting on the soil, as, for instance, cultivation, watering or drying. It is, therefore, at present impossible to measure or even define exactly what "tilth" means.

Condition of sub-soil.

Again the roots of plants penetrate down into the soil to a depth of several feet ; in the case of cotton the roots have been traced at Lyallpur to 15 feet depth. It is evident, therefore, that the physical condition of the soil below the top 6 or 9 inches cultivated affects the crop. The main agent in loosening the soil below the first 6 inches or 8 inches is the roots themselves. The roots force their way in all directions, and when they decay leave open spaces for air and water, and the organic matter left serves to manure the sub-soil in the same way as dung or leaves do the surface soil.

Case of new soils.

It is probably due to the fact that the lower soil has not been properly opened up that the first crop or two on new land is inferior and apt to disappoint the inexperienced. *The same soils after a couple of crops* yield very heavily as a rule.

Rotation.

Also one of the advantages of rotation of crops lies in the fact that deep rooting crops such as cotton, gram, etc., open out the soil excellently for the succeeding wheat crop. At Lyallpur wheat following cotton has given 10 per cent. higher yield over a number of years than wheat following wheat.

Other agencies affecting lower layers of soil.

The drying of the soil, which occurs to a depth of 2 or 3 feet after prolonged drought, must exert an influence on the sub-soil also. We know soils expand when wet and contract and crack on drying. Ordinarily every soil is moist below the top few inches, but after a prolonged drought the soil seems to get dry to a greater depth. It has been found at Lyallpur that summer fallow cultivation with a minimum of rain or watering has a better effect on the succeeding wheat crop than when water is applied or a wet year ensues. This loosening of the sub-soil by means of deep-rooted crops or by drying seems to suit crops like wheat and barley especially. The roots *of these crops spread freely to a depth of* 5 *or* 6 feet at least in such a soil, whereas they are unable to do so in hard sub-soil. Cotton is better able to force its way down into hard soil, and the condition of the sub-soil in its case would not appear to be so important. Maize and sugarcane, which are shallow-rooted, do not seem to be affected by the condition of the soil below top 2 feet or so.

The relative importance for various crops of loosening the sub-soil has been discussed above, but the condition of the surface 6 or 9 inches is of vital importance to all crops. All crops are sown in this surface layer and draw their entire mineral nourishment from this source during the first few weeks of their existence. Pests, unfavourable weather and other adverse factors are most potent at this stage in the life of the crop, so that its future is very largely dependent on its condition in the early stages of its growth. Again, most crops have 80 per cent. of their roots in the first 12 inches of soil. The tilth of the surface soil is very largely in the power of the farmer. It is the difference in the physical condition of this surface layer which is responsible for the good yields on well-farmed soil as compared to similar land indifferently cultivated. This is especially true for the Punjab, where manuring is comparatively rare except for certain crops. This emphasises the importance of cultivation as the only practical means of improving tilth that is within the reach of the farmer here. First class crops can be obtained on the alluvial soil of the Punjab with good cultivation and sufficient water without any manuring.

Importance of top layer.

Tillage operations may be divided into three periods—the fallow or preliminary cultivation, the operations connected with the sowing of the crop, and the after cultivation or intertillage of the growing crop.

Tillage operations.

Fallow cultivation means the cultivation of land which is resting. It should usually begin as soon as possible after the harvesting of the previous crop, and may be considered as ending when we start to prepare the seed bed. On irrigated land the beginning and ending of this period are generally sharply defined by two waterings. After the removal of the previous crop a watering called "wahn" is commonly applied in order to make it possible to plough it, and thus start the fallow cultivation; shortly before sowing another watering is applied called "rauni," and after this the soil is prepared for sowing without any further watering. If timely rain falls, the "wahn" irrigation is unnecessary.

"Rauni."

The second period includes the preparation of the soil for sowing, and the sowing and covering of the seed. This period may be regarded as ending when the young crop emerges from the soil.

The cultivation of the soil in which the crop is growing is usually possible with suitable implements, and is very profitable

provided that too much of it does not have to be done by hand labour.

For all these various operations the Punjab farmer uses ordinarily only two bullocks drawn implement, the country plough and "sohaga," supplemented by several hand tools. For fulfilling a large variety of functions these implements are unquestionably very efficient, especially when their small cost (a few rupees each) is considered, as well as the fact that very little iron is used in their construction; for until recent years iron was too dear in India to be used profitably in such things as agricultural implements. But naturally an implement, which is used for a variety of purposes, cannot perform each of them so efficiently as an implement designed for that special purpose. Hence, as far as the limit at which the interest on capital expended becomes too great, it is profitable to employ a number of different cultivating implements, such as ploughs, harrows, and hoes. Each of these implements is designed for only a very limited function, but will perform that function very efficiently and cheaply.

As has already been explained, land from which one crop has been harvested, and which is resting until the sowing of the next crop, is called fallow land. The changes in the store of plant food in the soil which take place during such a fallow are discussed elsewhere. The objects of cultivating the soil during such a period are to facilitate these chemical changes, to improve the physical condition of the soil, and to free it from weeds. In English agriculture the cleaning of the soil from weeds is the most important reason for fallowing. But in the Punjab, where weeds only grow freely when the soil is watered, or during the short rainy season, the fallow, though still important as an opportunity for cleaning the land, is more a means of storing up fertility rather than a necessity for the control of weeds. The fallow period may be extended for a whole year, as is the case in many districts on "barani" lands, where wheat is followed by a summer (kharif) crop such as "mash," "mung," or "moth." The land in this case is fallow for over a year until the next wheat crop is sown. In irrigated land the fallow is generally short, *e.g.*, only a few weeks in case of cotton following "toria," gram or sugarcane. Even in irrigated land wheat follows a fallow of some months, and is very rarely sown after a kharif crop. Gram, on the other hand, often follows summer fodder crops such as "chari" or "guara."

Fallow cultivation is generally done in the summer either after rain or with irrigation. Very little land as a rule is vacant during the winter, especially in irrigated land. In

"barani" land some winter fallow cultivation may be done if rains are good.

What fallow cultivation consists of.

Fallow cultivation consists generally in ploughing the surface soil so as to expose as much as possible of it to the weathering influence of sun, air and wind. If the "desi" plough is used, this means two or three ploughings, one of which will be cross-wise. With the iron plough one ploughing is sufficient as a preliminary measure. The land is often left in fairly rough condition, but it should not be in big lumps or clods if this can be avoided. After the preliminary ploughings the land is stirred periodically either by a native plough, or if a harrow is available, that is preferred. The object is to bring the soil into a fairly level and fine condition before final preparation for sowing takes place. Fallow land should always be stirred after rain, as otherwise the surface hardens and big clods may be formed. Owing to its slowness the plough is obviously not the best implement for this work, for a harrow doing 3 or 4 acres a day can easily cover the ground before the surface soil gets too hard.

Advantages of the iron plough for fallow cultivation.

By using the iron plough in the first breaking up of fallow land the soil is turned over and stubble as well as weeds buried, thus enriching the soil. The "munah" tends to collect stubble on the surface, and thus depletes the soil of fertilizing matter. Again the "munah" owing to its shape cuts a V-shaped furrow and leaves a considerable amount of soil untouched. This is why several ploughings with the "munah" are necessary where one with the iron plough suffices at this period. Again, apart from its inefficiency in burying organic matter the "munah" penetrates hard soil with difficulty, and when strong weeds are encountered, the draft is excessive. Weeds such as "kahi," "baru," "motha," and even "dub,"* tend to spread if only the "desi" plough is used. The exposure resulting from inversion by the iron plough causes the roots to dry and tends to clear the land of weeds. This aspect is very clearly noticeable when comparing two series of plots at Gurdaspur Government Farm. The only difference in the treatment of these plots is that in one the iron plough is used for the beginning of the fallow cultivation and the "munah" in the other. The latter plots are often very troublesome with "baru," whereas the former are quite clean and free.

Again, owing to the iron plough cutting through the soil instead of tearing through it, it is possible to plough to the

* For botanical names see chapter on weeds.

proper depth from the first, whereas with the "munah" the required depth of 5½ inches or so is often only properly attained by the third ploughing.

As pointed out above, it is not necessary for the soil to be in a fine state at the beginning of a fallow. Clods up to 3 or 4 inches across may be safely left, for they will mostly break down in the subsequent cultivation and by weathering. If too big, however, they harden and are very difficult to break up again if this is not done at once by means of the "sohaga." If the latter is used, it is necessary to plough again at once in order to open the soil. It is very common in the canal colonies to see fallow fields with big clods of this kind, as the farmer has neglected for some reason to "sohaga" and plough again at the proper time. Such land requires very heavy "rauni" waterings, and its tilth is never ideal at seed-time. The mould-board of the iron plough has a pulverizing action, and large clods are rarely left after its use if the land was anywhere near the right condition ("vatar"*) at ploughing time. Subsequent to ploughing either with a "munah" or iron plough, if an implement like the spring-tinned-harrow or the drag-harrow or the horse-hoe is used, the clods can be easily broken at very little cost as compared to frequent ploughings.

The subsequent tillage of fallow land depends largely on rain. It should be, as pointed out above, broken up always after rain and before the surface hardens. This is easiest done with a harrow which can do 3 or 4 acres a day. If no rain falls, harrowing once every three weeks or a month is sufficient cultivation, and this tends to help the weathering and levels the soil prior to "rauni." Before applying "rauni" it is advisable to use the "sohaga" to level the soil and assist the flow of water, thus getting a more even distribution and economising water.

The above description applies in the main to "irrigated" and "barani" fallow cultivation. In the latter, however, the preservation of moisture is of primary importance. Hence cultivation after rain to preserve moisture is most essential. The ideal thing in "barani" land would be to break the soil before rain, but this can generally only be done by a disc plough or disc harrow, and the cost of that is prohibitive for general use.

If only indigenous implements are used, every rain must be taken full advantage of and the land ploughed as deep as

* Land is said to be in "vatar" when it is in condition for ploughing, and will break up easily when implements are used over it. Cultivation at this time saves labour and trouble afterwards.

possible. As a rule subsequent rains enable the proper depth to be reached by the second or third ploughing. The clods should be broken up by "sohaga" towards the end of the period, but it is unadvisable to have the surface fine and smooth, as in that condition rain destroys tilth easily. Attention to summer fallow cultivation at the Gurdaspur Government Farm accounts for the generally much better yields obtained there as compared to surrounding "barani" fields of similar quality. There is undoubtedly a large scope for the introduction of more suitable implements on "barani" tracts so as to make full use of the draft power available.

Implements suitable for fallow cultivation.

The implements which would appear to be most useful for "barani" tracts are horse-hoe, spring-tinned-harrow or drag-harrow. The first two are expensive, but the latter costs a moderate sum of Rs. 23 only at present, and will do efficient work. Disc harrows, though still more suitable, especially for heavy land, are too expensive to recommend. The above three implements will cover from 3 to 5 acres a day, and their work resembles that of the "munah" in that they stir the soil without inverting it. They enable the cultivator to cover his whole fallow area quickly, and thus, in case of only light preliminary rains, the subsequent ploughing is easier. If early rains are sufficient, they enable the soil to be put in a condition which conserves the moisture through the surface mulch which they form. The land can be then ploughed at leisure. It will be seen that harrowing in "barani" land is of great importance, but ploughing should also be done as early as possible in the fallowing season, and for this the furrow-turning iron plough is recommended.

The practice in irrigated land of giving a "rauni" watering, even if the rains have been fairly good and the soil contains fair moisture, is general. One of the reasons for this is that "rauni" does not destroy tilth as the soil is cultivated afterwards when in "vatar". The giving of a watering may help to prolong the date of "kor" or first watering after sowing, and this is everywhere regarded as being good practice. There is no doubt that once "kor" watering is given the presence of the growing wheat crop prevents much being done by tillage to keep the land in tilth. Harrowing by means of the "bar-harrow" does some good, but to be really deep enough to get perfect tilth would cause injury to the young roots of the crop. Thus once a thickly growing crop like wheat is sown, very little can be done by way of effective after cultivation.

After "rauni" irrigation the land is in "vatar" and ready for sowing in the hot season after 2 or 3 days in the case of light land, and 3 or 4 in case of heavy land. In October, or at the beginning of the rabi sowing season, the period is about 5 or 6 days, and later 10 to 12 days. As a rule sowing should be done as soon as land is in "vatar," and this is especially so in case of shallow sown crops like "toria" and cotton. While at the beginning of the wheat sowing season it is advisable to sow as soon as the plough can be used on the land, *i.e.*, in 5 or 6 days after "rauni," later on in November, when the land may take 8 to 10 days to come to "vatar," it is a common practice to do "dáb". This consists in giving the land two or three ploughings at intervals of 4 or 5 days between time of "vatar" and sowing. This undoubtedly causes some loss of moisture, but is very useful in cleaning land, as weeds, such as "bathu," "piazi," etc., which germinate at this period, are effectively destroyed by the cultivation that takes place. Poli, which germinates later, is not affected. This process is only advised in case of weedy soils and where western implements are not available.

Period between "rauni" and sowing.

In irrigated land especially the surface should be as level as possible to facilitate even distribution of water during irrigation. Generally the soil should be uniformly fine and soft for the reception of the seed. It is not advisable to have too great a depth of loose soil, as otherwise the passage of moisture upwards is retarded. To compact the seed-bed somewhat, the "sohaga" is used in ordinary practice. If necessary it is weighted by two men standing on it. After this compaction the actual surface may be harrowed to a suitable depth, thus forming a "mulch" for preservation of moisture. Even in case of "toria" a shallow mulch of 1 inch depth appears advisable. Cotton can do with 2 inches and wheat with even 3 inches. The mulch must not be deeper than the depth at which the seed is sown.

Condition of seed bed for various crops.

In the case of some crops, *e.g.*, "gram" the surface is often left irregular with even small lumps or clods of earth. This crop is generally sown deep in light soil, and if thus sown after the plough, is generally not subjected to the "*sohaga*," as that might obstruct the passage of the young shoots above ground, and also mainly as it would make the soil less open for air. Throughout the treatment of the seed-bed it is necessary to keep the moisture fairly near the surface, as once it dries by being left long in a loose condition, it is difficult to get the moisture up again. This point is of great importance with summer crops when land dries

very quickly, and where in consequence the right condition for sowing is more difficult to attain and keep up. The seed itself must be deposited in moist, fairly compact soil in all cases. The bar-harrow is extremely useful in connection with the formation of a surface mulch after sowing.

Advantage of country plough.

In the work of preparing the seed bed the country plough has an advantage over the iron plough in that it does not spoil the level of the field. And as the soil at this stage is usually already soft and loose, the country plough and "sohaga" will do quite good work. The "sohaga" is used after each ploughing to break the soft clods thrown up by the plough, and will give a finishing touch to the levelling if this is needed. In one part of the Punjab, which comprises parts of the districts of Multan, Muzaffargarh, and Jhang, and also in Rohtak and Karnal, a wooden roller is used instead of the "sohaga." As explained elsewhere (Chapter V), the roller is more efficient in the breaking of clods; and the compressing effect of the roller goes deeper and compacts the soil into the sub-soil. It is thus more effective in bringing the moisture to the surface than is the "sohaga", the effect of which is more superficial. The roller may be necessary in those parts where the soil is heavy and the inundation canals close early, and a roller would sometimes be useful in other parts. But it is believed that it would not be advantageous generally to replace the "sohaga" by the roller on irrigated land, as the levelling effect of the former is so important. A roller should only exceptionally be needed for clod crushing on irrigated land under good management; and with perennial irrigation a perfectly moist seed-bed can be ensured with little difficulty.

Case where iron plough is used.

Generally the country plough is advised for operations just before sowing in preference to the iron plough except when no fallow period is available. Thus when sowing cotton after wheat or gram, it is best to use the iron plough to bury the stubble. It must, however, be followed by the "sohaga" and harrowing in order to ensure the land being level before sowing.

Seed-bed in "barani land."

The process is similar to that on irrigated land except that the preservation of moisture and of a moist seed-bed is more vital. The former is attained by repeatedly working the "sohaga." It has been suggested that the "roller" might be used with advantage. The matter is one worthy of careful study. The main difficulty is an economic one, and it might be difficult to recommend an implement which in some years of good rainfall may not be

required. There are, however, probably several tracts where the use of the roller could be extended with profit.

Sowing.

In sowing we have to ensure not only plentiful and regular germination, but the thriving of the young plant during the first few weeks of its growth. The conditions necessary for germination are given in Chapter II. The three essentials are air, moisture, and the right temperature. *To ensure air the seed would be best deposited in* loose soil near the surface. In this case, however, with the dry climate of the Punjab, the moisture supply would be inadequate and the seed, even if it germinated, might wither up. To ensure moisture, therefore, the seed must be in compact soil in touch with the reserves of water below. If planted too deep, the air supply may be deficient and the young plant may find it physically impossible to force its way through. This probably accounts for the practice referred to above as common in "barani" land to sow wheat and gram behind the plough or by "pora", and leaving the field open without using a "sohaga." The seed is thus left in touch with moist firm soil with quite loose soil above, and can thus on germination force its leaves above surface easily. In irrigated land, where optimum conditions of moisture are more easily attained, seed is sown usually much shallower than under "barani" conditions. Irregular germination of seed means a loss of yield even if actually a sufficient number of plants eventually germinate. The later plants never thrive as well as others, and thus start with a handicap. When the germination is so faulty as to leave blanks or patches of soil without plants, the loss in yield is considerable. It is estimated that from this cause alone cotton and "toria" in the colonies suffer to the extent of at least 10 per cent.

Temperature.

As regards temperature, the question mainly affects rabi crops. Early sown wheat, if the soil is not cool, is often lacking in vigour and very liable to attack by white-ants, or to suffer from early frosts. Again very late sown wheats are so backward that the yield is depressed often 30 per cent. or more. In irrigated land the sowing is determined by the supply of water, and necessarily extends over 6 weeks or 2 months. In this respect "barani" land has an advantage, as date of sowing there is governed most by labour available. In irrigated land sometimes, in order to avoid waiting for the land to dry sufficiently for sowing after "rauni," the seed of late sown wheat is put in before "rauni" in dry soil. In such cases it is very advisable to harrow when the land is in "vatar" or the young crop is a couple of inches above ground.

In the Punjab there are three methods of sowing commonly used for field crops—"Chhatta" or broadcast sowing, "Kera" or dropping seed in the furrow behind the plough, and "Pora". In the latter method the plough is used as a one-rowed drill by tying a tube behind it.

Methods of sowing.

The well-known proverb—"Pora Badshah, Kera Wazir ta Chhatta Fakir"—would suggest that "pora" was invariably the best under all circumstances. As applied to a crop like wheat, it is probably in the main true. For small seeded crops, however, broadcast sowing is essential. The machines used in the West for such seeds are essentially mechanical broadcast distributors. Even in the best farming districts in Great Britain, broadcast sowing by hand is still common. The two main defects of broadcast sowing are (1) uneven distribution and (2) irregular depth of burying the seed. The latter is a question of good management and cultivation, and is not generally serious. The former, however, is important. A great deal depends on the skill and patience of the sower. A good practice is to go over the land two or three times, *i. e.*, dividing the seed into two or three lots and sowing two or three times, as the case may be. Also if the seed rate is small and the seed of small size, it is advisable to mix it with dry earth, and thus get a bulk more easy to evenly distribute. Broadcast sowing is eminently adapted for such crops as "toria," "sarson," "senji," "shaftal," etc.

In the simplest form of broadcast sowing the land is watered ("rauni"); the seed is scattered on the level ground as soon as it is dry enough. The seed is then covered by giving one ploughing, followed or not according to circumstances by the "sohaga." In fact, in the case of "senji," when sown, as it usually is between the plants of ripening crops of cotton or maize, the seed is simply scattered on the soil whilst it is still very wet, and buried by treading in with the bare feet.

Ordinarily, however, the soil is allowed to come into a suitable condition for ploughing before the seed is scattered, and the land is ploughed directly after the sowing. It will be observed that in these cases the seed-bed is not prepared at all, and the only cultivation the soil receives is this one ploughing. This, is the roughest, cheapest [and quickest method of sowing possible. It is useful in the case of crops which are able to establish themselves in a rough seed bed, and which are so

uncertain, or give such a comparatively small return that the farmer's profit is likely to depend more on the reduction of the cost of cultivation than on ensuring a maximum return. It is such reasons that justify, or partially justify, this method for sowing gram, especially in the "wadh" of another crop such as "chari" or for sowing kharif crops on "barani" land. The promptness with which considerable areas can be sown as soon as the soil is cleared of another crop, or as soon as it is dry enough after rain or watering, is another advantage of this method, and sometimes a matter of considerable importance. This also helps to justify the use of this rough and ready method in the two cases already instanced, and also in the sowing of cotton on wheat stubbles. At the best, however, this is a very crude way of doing broadcast sowing, for the soil is left very rough, the seed is very irregularly covered, and much of it cannot be properly brought into contact with fine earth. It is a rough method, which is never really good, and would be fatal with crops that were not very hardy.

Ordinarily the seed-bed is more thoroughly prepared by some degree of cultivation, and using the "sohaga" to get the soil level and compact. The depth of sowing is regulated by the kind of surface on which the seed is sown and by the method of covering. For very shallow sowing, the seed, when sown on land after the "sohaga" has levelled it, is covered by dragging a bushy branch of the "kikar" tree over the land. "Toria" and "sarson" are often sown on land left rough after the native plough. The seed is covered by levelling with the "sohaga." Again the soil may be levelled with the "sohaga," seed sown, land ploughed and levelled afterwards. This tends to get the seed deeper than is suitable for "toria." The deepest sowing is done by the following method :—

Sow on a rough surface after ploughing, plough again, and use the "sohaga."

There is little doubt that if harrows come into general use, a great improvement can be made in this method of sowing, for with harrows it is possible to control more accurately the depth at which the seed is covered, and besides they cover three or four times the ground done by the "munah." The "sohaga" or some similar implement will, however, need to be used even with harrows so as to leave the soil fairly compact.

"Kera" sowing

"Kera" is used where the seed-bed has been brought to some degree of fineness. It consists in a boy or woman following the plough and dropping

the seed in the furrow a few yards behind the ploughman. The next furrow throws an inch or two of soil over this, and by the subsequent use of the "sohaga" the seed is covered 3½ inches or so deep. This method is much in vogue in the canal colonies for wheat, and to some extent for cotton. The depth of sowing by this method is not very flexible, and it is unsuitable for that reason for use with small seeds. Much skill is not required, as in the case of "pora", and the method is therefore very common both in irrigated and to a less extent in "barani" land. The land in irrigated tracts has to be levelled with the 'sohaga" to facilitate subsequent waterings.

"Pora."

In sowing with the "por" a seed tube ("por" or "nali") is attached to the plough in such a way that the seed drops just behind the "chow" in the "munah," and under it in the case of the "hal," as in the latter it passes through a hole in the "kur." The seed is thus deposited right on solid earth at the bottom of the V-shaped furrow, and is partly covered by soil falling back behind the plough. The next furrow adds still more soil. Usually the "sohaga" is not used after "por" sowing, as the seed would thus be too deeply covered. In this method the ploughman drops the seed into the funnel-shaped mouth of the tube As some blanks are apt to occur in turnings, it is a common practice to sow a few rows diagonally across the fields after finishing in the ordinary way. Shallower sowing can be done, if necessary, by taking the "por" higher and further from the "chow" so as to imitate "kera". This is not common, but is sometimes done on well land.

By sowing with "drills" (see Chapter V) the seed is dropped in much the same way as by "por," except that the quantity is regulated by the number of tubes. There are two tubes in the case of kharif drills and three in rabi drills. The most important advantage from using drills is that it facilitates after cultivation in case of kharif crops. In the case of rabi crops time is saved. With drills it is possible to see at a glance when blanks occur after the crop germinates; whereas in broadcast sowing such blanks are more easily missed, and hence the chances of resowing blanks is missed until it is too late.

Use of harrow after sowing.

In irrigated land, as pointed out above, the passing of the "sohaga" over the land after sowing is the final operation. As this implement is apt to leave the surface somewhat hard and shiny, it is very advisable to harrow lightly afterwards. For this the bar-harrow is eminently suitable. This light harrowing improves germination

very visibly and prevents caking of the surface in case of subsequent showers of rain. The use of the harrow in this way for cotton is becoming widely appreciated in canal areas. Such harrowing only costs 4 to 6 annas an acre. This process is recommended particularly for general use in the case of cotton, and also for " toria," wheat, and even sugarcane.

After cultivation.

Unless rain falls, when it may be advisable to harrow, nothing further is usually done until the seed has germinated and has about two leaves above ground in addition to the cotyledon leaves. Subsequent operations are described in the chapters dealing with the various crops. The main advantages of such after-cultivation or interculture (vernacular "godi karna") is that it tends to maintain tilth. This latter is obtained with great labour during the fallow and sowing time operations, and should be maintained as long as possible for the growing crop. Irrigation or rain tends to destroy it; also the lack of humus in the soil in the Punjab plains renders loss of tilth easy. By stirring the soil and breaking the crust after irrigation more air can also enter the soil, thus helping in the formation of plant food and keeping the roots healthy. This interculture is especially necessary in the case of cotton, for which preliminary cultivation, as compared to wheat, is generally very hurried and short. Further, the mulch formed by interculture prevents excessive evaporation of moisture and saves watering, or enables the farmer to delay watering without injuring the crop. Delaying the first watering is often very important, as by this means the roots are encouraged to go deep into the soil instead of concentrating at the surface. Once the roots get well down, the crop is protected to a large extent from suffering by subsequent drought.

Another great advantage of interculture is that it helps to keep down weeds, especially in the summer season. A crop like cotton is particularly sensitive in this respect, and wherever much grass, such as "dub", is allowed to grow with it, the yield suffers very seriously. The condition of some of the cotton fields, particularly in parts of the colonies, shows what a large field for improvement there is in this direction. Hand labour is too expensive, and reliance must be placed on bullock power, for the use of which sowing in lines is a necessary preliminary.

Harrowing.

After-cultivation may consist of harrowing, whereby the whole field is covered irrespective of the position of the plants. This is only feasible

with small plants or in the younger stages of the growth of plants like cotton. Wheat, sugarcane, and maize can generally be harrowed till the plants are from 6 inches to a foot above ground Harrowing can be done in broadcast as well as line-sown fields. In the case of crops sown some distance apart, *e.g.*, cotton, sugarcane, maize, etc., the after-cultivation in later stages is done by implements drawn between the lines. Such implements are the "Horse-hoe" and "Lyallpur-hoe," the use of which is spreading satisfactorily Hand implements used for this purpose are the "khurpa" and the "baguri." Sometimes the country plough is also used (see Chapter XI).

CHAPTER V.—TILLAGE IMPLEMENTS.

Necessary to value cost of bullock and manual cultivation.

Before studying the methods of cultivating the soil it is necessary to understand the working of the different implements used, though this is more thoroughly explained in chapter on cultivation. Moreover their costs, and especially the costs of working each, must be understood before the different metheds of cultivation can be intelligently studied. The cost of purchasing implements is never in danger of being overlooked in India; but it is sometimes suggested that so much attention need not be paid to the cost of carrying out the various operations, since wages are very seldom paid; or when given are frequently not paid in money, and very little cattle food is bought by the farmer. But, unless some definite and fairly accurate figure is used, as the price of a day's work by bullocks or men, it is impossible to proceed far in the systematic study of Agriculture. For instance, we cannot otherwise estimate the advantages of using an implement pulled by bullocks, and doing the same work by hand; nor is it possible to compare the relative profits from two different crops unless we can estimate not only the respective returns from their sale, but also the relative amounts of labour and money (chiefly in the water-rate, revenue, etc.) expended in their production. Thus the returns from an average crop of sugarcane may be about Rs. 200 per acre, and from an average crop of wheat only Rs. 100 per acre; yet it is not true that sugarcane is twice as profitable, or Rs. 100 per acre more profitable than wheat. For much more labour, both by men and bullocks, more manure and more water have to be expended to produce the sugarcane than the wheat, and the sugarcane occupies the land much longer and usually carries higher revenue rates. It is thus only by expressing the use of the land in terms of rent, and the amounts of bullock and manual labour, manure, and water expended at their estimated cost in money, that we are able to compute the cost of growing two different crops, and thus to lay the foundation for the comparison of the relative advantages of these crops.

Difficulty of estimating costs.

At the same time it is exceedingly difficult accurately to fix a figure as the cost to a farmer of a day's work by his pair of bullocks. Practically every figure used in the calculation has to be estimated. Thus the bullocks are probably bred by the farmer himself, not bought; they may live a comparatively long life or may die young from

accident or contagious disease; the food they eat cannot be reckoned at market price, since its value in a village depends considerably on the situation of the village; and the estimation of the value of the animals' dung is as complicated and liable to error as all the others together. Moreover, practically all these figures vary from place to place, from season to season, and from year to year. Even the adoption of a general figure for a man's daily wage is not easy, for this varies according to the place and the time of the year, and lately has also varied considerably from year to year.

For general figures it is fairly satisfactory to adopt Re. 1 as the price of a pair of bullocks for a day and 8 annas as the price of a day's work by a labourer or tenant; for special purposes it may be necessary to modify these figures, as, for instance, in harvesting when labour is usually very scarce, or in sugarcane crushing when there is little work for the bullocks, or in certain special parts of the province where conditions are different. Even allowing for such considerations, it is easy to criticize these figures; and it is equally easy to make quite reasonable calculations to show either that they are too high or that they are too low. Fortunately most of our conclusions would be little affected by any reasonable variation of these figures; for we are usually concerned with comparisons, so that, provided the figures adopted are fairly nearly correct and the same figures are used on both sides of the comparison, no great error will be introduced.

The plough.

The most important agricultural implement is generally the plough, and it will be convenient first to consider the country "munah" and "hal" (see figures 1 & 2), since these words are generally translated as "plough." And it is from somewhat similar wooden "ploughs" used with bullocks that the modern horse-drawn western ploughs have developed, though the western plough as now known (see fig. 3) is very different; and in fact the western heavy harrow or "cultivator" does work more resembling that of the "munah" or "hal."

Functions of a plough.

The functions of the modern plough, which are generally regarded as most essential, are cutting off the layer of soil from the "sub-soil" below and inverting it so as to bring the lower part to the top. Although some modern ploughs (such as those introduced to this country) do also break the soil to some extent, this is not always the case, and this is not regarded as an essential part of the plough's duties. Moreover though the depth can be varied to some extent, the iron plough is used to cut down to full depth at once, and is not adopted to work

RAJAH PLOUGH

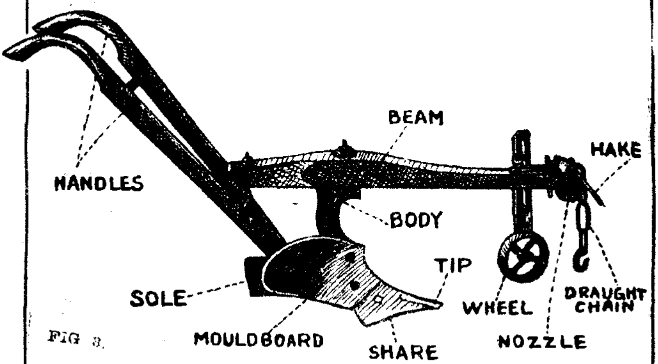

FIG 3.

MESTON PLOUGH

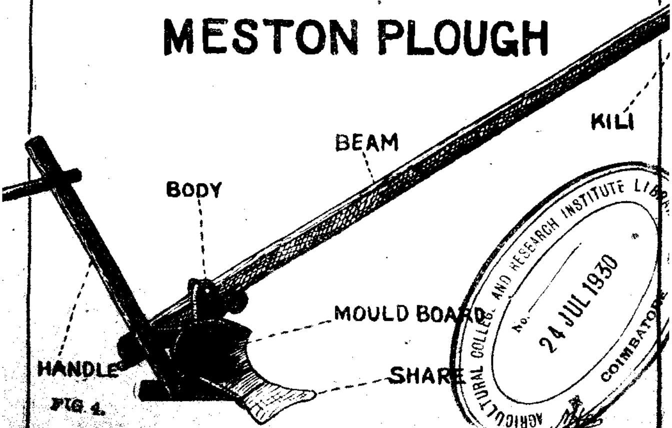

FIG. 4.

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very shallow if the soil is hard. Harrows and cultivators can be used for shallow work if necessary, and the stirring and breaking up of the soil are their most important functions; they are not so efficient in cutting off the soil completely from the lower layers or in turning it over. The country plough is most efficient for stirring the soil and breaking it up; it is not very effective in cutting the top layer of soil, and it does not entirely invert all the soil it loosens. It can be used to scratch to a small depth a soil which is too hard to plough properly.

Work of Indian ploughs.

The essential part of the native plough ("chow" in "munah," "kur" in the "hal") consists of a tapering triangular block of hard wood (commonly "kikar" wood); in Punjab ploughs the base of the triangle is uppermost. The point at the forward end is protected by a pointed iron "share" ("phalla") fixed above it. (See fig. 1).

As the plough moves forward, this point, being inclined downward, is forced into the soil and tears out a V-shaped groove or furrow in much the same way as a gauge cuts into board. The expanding sides behind the point partially turn the loosened soil over and also break the earth at the sides. Earth being friable, the furrow is not cut exactly in a sharp V, but is broken to some distance on both sides of the furrow. But as the "chow" is narrower below than above some earth is always left untouched between the furrows, so that if the loosened earth is swept off, the surface of the hard earth beneath is corrugated or wavy. The other parts of the plough are in the case of the "munah":—

Hals	or	beam;
Munah	or	body;
and Hathi	or	handle (see fig. 1).

In working the country plough there are a few points to attend to in which the skill of the ploughman is displayed. The angle at which the "chow" enters the soil can be adjusted so that it maintains an even depth. If the angle is too great, the plough proceeds in a series of jumps, doing very poor work, and making heavy labour for the bullocks. A plough in this condition is spoken of in vernacular as being "okru." The plough should be so used as to leave a minimum amount of soil untouched between the furrows; this is especially important at the corners. For as the country plough is worked round and round the field, turning to the left, and hardly ever taken out of the soil, there is a great tendency to miss a good deal of the land at the corners. Sometimes, especially in sowing, a number of diagonal furrows are ploughed in order to finish off the soil thus missed.

The draft of a medium sized "munah" when cutting to a depth of 5 inches in loam soil varies from $1\frac{1}{2}$ to $1\frac{3}{4}$ cwts.

The furrows are then from 8 to 10 inches apart. As about one acre is ploughed in a day, the cost of ploughing an acre may be taken at about Re. 1-8.

The cost of a "munah" is about Rs. 5 and of a "hal" Rs. 6.

Life of country plough.

The life of a "munah" may be said to be five years. The iron share is replaced twice a year and the "chow" once a season. A share and a "chow" cost Re. 1 each.

Small types of "munah" and "hal" are used in hilly tracts where the cattle are small, *e.g.*, in Jhelum, Kangra, and Rawalpindi.

Essential features of furrow turning plough.

The way in which the iron plough works, although really very simple, is not immediately obvious owing to its smoothly curved shape. It is most easily understood by constructing a model out of paper or tin. Supposing an oblong sheet is folded down the middle till it forms a right angle, and this is fixed into the soil and pulled forward with one side horizontal and the other vertical, it will cut off the rectangular strip lying in the angle. But the work will be greatly facilitated by sloping off both sides at the front; the cut soil, however, would lie in its original position, and all that we should have done would be to separate it by a cut.

If, however, we now bend the vertical side over to the right, *then, as we drag it forward, the soil will be displaced to the right* end turned over.

Such a model will represent the essential parts of an iron plough. The forward part corresponds to the share and the rear portion to the mould board. The share and the mould board of an actual plough (fig. 3) only differ from our model in that they are shaped with smooth curves in order to lessen the friction.

It will be seen then that the function of the share is to cut off the "furrow slice" of soil by a horizontal and a vertical cut, and that it is so shaped as to do this as easily as possible. The mould board turns over the slice so cut to the right, and in so doing also shifts it to the right. The mould board and share are always made as two separate parts; this is because the share, doing the cutting work, gets worn out much more rapidly than

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N. B.—The ploughs used in the Punjab are all right handed, and the remarks here refer to such: some ploughs are built the opposite way and turn the soil to the left.

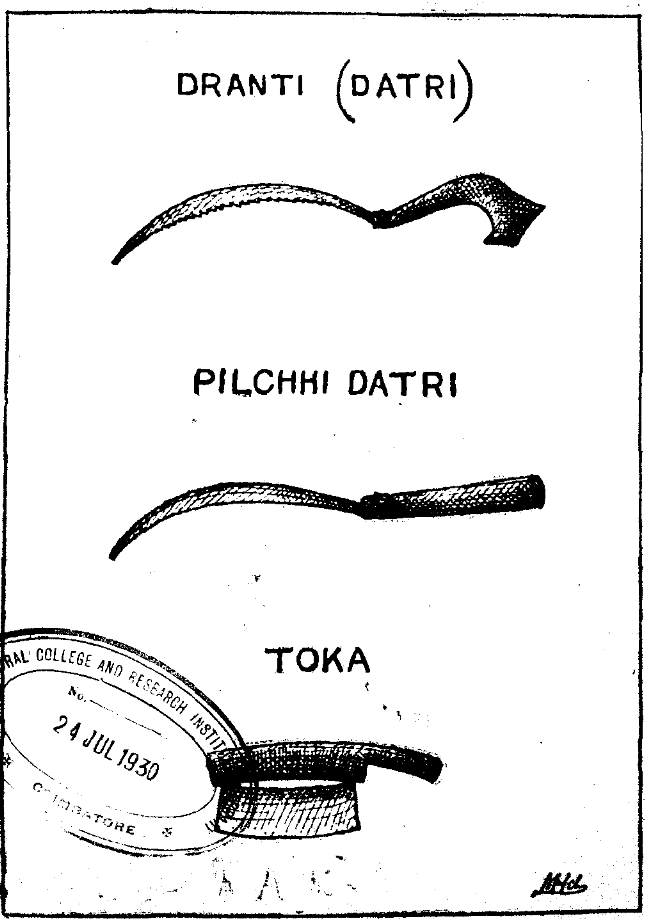

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FIG. 14.

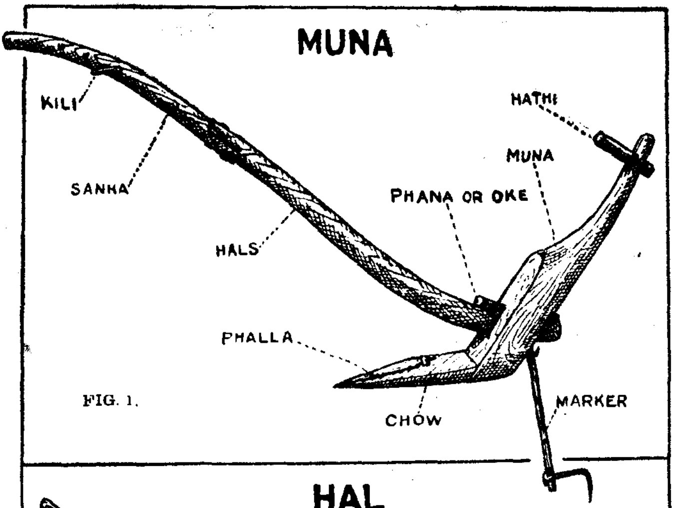

FIG. 1.

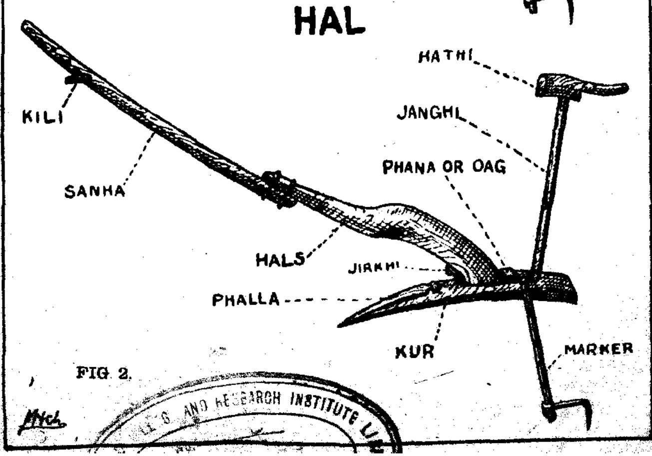

FIG. 2.

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the mould board. For the same reason the point of the share is also frequently made separate from the remainder, so that when the point wears the whole share need not be replaced.

Life of share and point.

The share wears out after doing 30 acres in a medium soil and point after 10 acres.

Other parts of the iron plough.

The other parts of the plough serve, as it were, as a frame to hold the share and mould board so that it can be pulled by bullocks. The lower surface of the land-slide (fig. 3) serves to support the plough horizontally on the ground, and its side takes the pressure against the unploughed earth. The functions of the body, beam, and handles are obvious. The nozzle and "hake" serve to regulate the depth by altering the point of attachment of the draught chain. Raising the point of attachment in the nozzle, tilts the front of the plough down into the soil and makes it run deeper; shifting attachment in the hake in the same way alters the direction in the horizontal plane; moving the attachment to the right, points the plough to the left, making it cut a wider furrow; and moving it the left has exactly the opposite effect.

Draught of the iron and "desi" ploughs.

Comparison of draught with country plough.

Many measurements of the draught of the iron plough as compared to the country "munah" have been made by means of a dynamometer attached to the yoke. The figures relate to soil at Lyallpur in a condition fit for ploughing, and are as follows:—

			Furrow.	Draught.
I	Munah	...	5″ × 8″	$1\frac{5}{8}$ cwts.
	Rajah	...	6″ × 9″	$1\frac{7}{8}$,,
II	Munah	...	$6\frac{1}{2}$″ × $8\frac{1}{2}$″	$1\frac{5}{8}$ to $2\frac{1}{2}$ cwts.
	Rajah	...	$7\frac{1}{2}$″ × 12″	$1\frac{1}{2}$ to $2\frac{1}{2}$ cwts.

In the above tests the natural size of furrow for the plough was taken. In case II the iron plough was new, and hence cut a very wide furrow. As the soil dries, the draught increases much more rapidly in the case of the "munah" than with the iron plough. This is as expected, for the cutting action of the latter facilitates ploughing in hard soil.

Difficulties with iron ploughs.

The iron plough, such as the Rajah or Punjab, is not so easy to control in some respects as the "munah" The actual leverage obtainable is greater, and much more uniform ploughing can be done with it than with the "munah. The cattle are, however, further away from the plough.

man, and reins as well as a long stick is necessary as a rule with iron ploughs.

Again, owing to an open furrow being left after the plough, the land is apt to get unlevel, a very important objection in irrigated land. This can be corrected by making a centre opening instead of ploughing from the sides of the field, as is done with the "munah." In making an opening four shallow furrow slices are generally made in the middle of the field. These when finished leave a shallow furrow with two furrow slices on each side. These are then turned in towards the furrow by two more turns. The depth is then increased, and ploughing proceeds in the ordinary way. In this way there should be no high land in the middle. There will, however, be furrows at the two sides of the field, and these can be filled by the "sohaga" when levelling.

The iron plough is particularly useful in weedy fields, as it buries weeds and helps to keep the land clean, very much better than the "munah" or "hal".

The cost of the iron plough is now Rs. 59. The share costs Rs. 3-10 and the point Re. 1-2 at Lyallpur. The point wears out after doing 10 to 12 acres in sandy soil.

Ploughs recommended for the Punjab.

The Rajah and Punjab ploughs are recommended for those possessing 50 acres or more (see fig. 3). These ploughs are not required for all ploughing done, as once the soil is thoroughly opened the "munah" does the work well enough.

For men possessing less than 50 acres and for others also, especially in "barani" tracts, the Meston plough is recommended (see fig. 4). This plough costs Rs. 19-8 and the share costs 15 annas only, and has to be replaced generally after doing 15 acres. The attachment in this plough is by a "beam," and hence is similar to that of the Munah. It inverts the soil, and its draught is less than that of the Rajah.

Harrows, etc.

Harrows, horse-hoes, and cultivators of the various sorts are implements consisting of several, or even a number, of teeth affixed below some kind of frame intended for stirring the soil and breaking its surface. They may primarily be divided into two classes. The heavier implements, which work down to a considerable depth, have fairly broad points ; they will tear through considerable obstructions, and can thus only be used on fallow land or between the rows of a crop. Light harrows, on the other hand, have many

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BAR HARROW

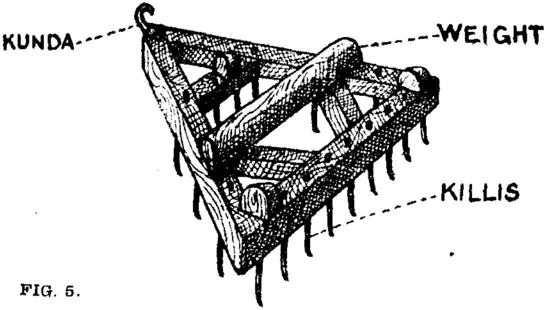

FIG. 5.

DRAG HARROW

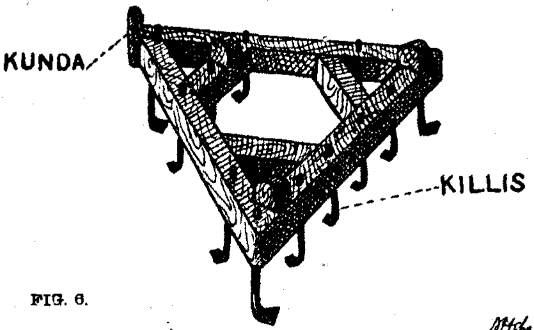

FIG. 6.

fine points. Owing to their slight weight, they can be used on many crops (after they have been sown) without dislodging the seed or tearing up the plants.

Spring-tined-harrow.

The spring-tined-harrows, which have been recommended for use in the Punjab, are intended only for use on land on which no crop is growing. They can hardly be used for cultivating between the plants of a wide-sown crop, for they can hardly be directed with sufficient accuracy to avoid the plants. The springiness of the points helps, because when serious obstruction is encountered by one of the points or "tines", this one will bend without throwing the whole implement off its level and without breaking. It has also been suggested that the continual vibration of the tines helps in breaking up the clods. The necessity for making the springs of good steel renders the implement distinctly expensive. And the expense of springs hardly appears generally necessary in the Punjab, where the fields are commonly free from stones, rocks, roots of trees or other obstructions. Moreover, the springiness of the tines prevents them from satisfactorily tearing up a grass like "dub," which grows in matted patches on the surface of the soil. The frames of the small spring-tined-harrows sold in India are not really strong enough to wear well.

"Horse-hoes."

The "horse hoes" recommended for use in the Punjab are adapted for use either on fallow land or between the plants of a crop sown in straight lines fairly wide apart; they are very useful for cultivating the land between cotton plants when this is sown in lines as it should be. The width of the horse-hoe can be varied from 18 inches to nearly 3 feet; and it can be directed fairly accurately by the driver holding the handles. (See Fig. 8.)

The drag-harrow.

The foregoing implements, *viz.*, the spring-tined-harrow and the horse-hoe, cost respectively Rs. 92 and Rs. 80 as compared to Rs. 23 for the drag-harrow. This implement is an adaptation of the bar-harrow described later. It is capable of good work and designed to replace the spring-tined-harrow, which is too expensive for general use. (See figure 6).

The bar-harrow.

This is a light harrow, of triangular shape with 17 steel points, attached to a triangular frame. It was designed to replace the lever-harrow commonly used in the United States of America. The tines are made to point slightly backwards to avoid uprooting young growing plants as much as possible. Its width is 4 feet, and it

will cover 4 to 6 acres in a day of 10 hours. It is useful for harrowing any crop in its early stages, particularly wheat, cotton, toria, sugarcane, and for breaking the crust after showers of rain. This implement costs Rs. 19 to make at Lyallpur, though they are being sold at Rs. 12 to encourage their use. Over a 1,000 have been sold. (See fig. 5.)

Lyallpur-hoe.

This is a small three tined implement made by the Agricultural Department. (See fig. 7.) Its final form is not definitely fixed, and the Agricultural Engineer (Mr. Brownlie) and Mr. Faulkner are working on an improved and stronger type. The type already evolved costs Rs. 11 at Lyallpur, and sells fairly well.

Advantages of harrows.

It will readily be seen that it is much quicker and cheaper to work over a field once with one of these hoes or harrows than once with a country plough, the saving being proportional to the width of soil covered by the implements. Thus if it costs Re. 1-8 to plough an acre with the country plough taking a 9 inches furrow, it will only cost about 8 annas to harrow with an implement 2½ feet wide, or if, in hoeing cotton, it is necessary to pass the country plough two or three times between the lines of plants, this will cost two or three times as much as hoeing with an implement which is wide enough to cover the whole area between the rows at once. Now these implements obviously cannot be worked to such a great depth in a hard soil as can the country plough ; for if they were so used, their draft must obviously be much greater than that of the country plough, since they cover a much greater width. Nor do they perhaps turn the soil over or crumble it up so much as the country plough. But, as will be seen in the next chapter, there are many occasions when the soil is not very hard, and where it is not necessary to work very deep or to turn the soil over, but when it is only necessary to loosen the soil, stir it, and break down soft clods. In such cases the horse-hoe or heavy harrow can be used with great economy. An instance of this is after the use of the iron plough. Once ploughing moist land with an iron plough and two harrowings will leave it in a much better condition than three ploughings with a country plough, and the cost will be considerably less. Again, when a considerable area of land has been irrigated, or rain has fallen, it is often very important to break up the surface of the soil quickly before it hardens again ; it does not much matter if the work done is not very deep ; the important point is that the whole area should be covered quickly. In such circumstances the profit from the use of a heavy harrow or horse-hoe may be very considerable.

LYALLPUR HOE

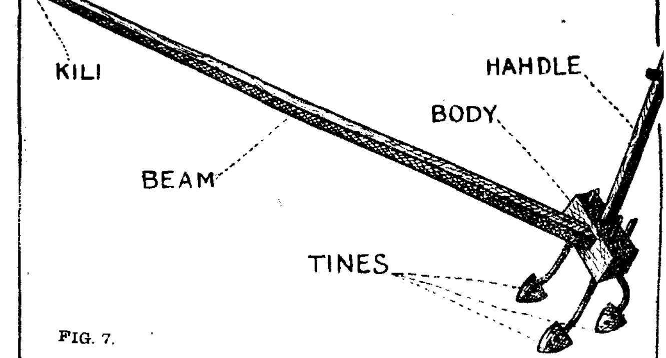

FIG. 7.

HORSE HOE

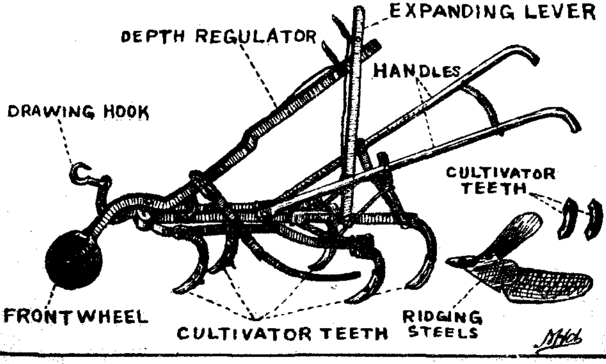

FIG. 8.

"Sohaga" and rollers.

"Sohaga" and rollers are both used for breaking clods; but it is necessary to distinguish clearly between their effects, for there are very important differences in the action of these implements. If the work of a roller is observed, it will be seen that it compresses the soil and crushes any clods on it. This it does very effectively, for it is heavy and the weight all acts downwards and on the small area of soil touching the bottom of the roller. But it does not to any appreciable extent shift any earth from one place to another. In so far as it levels the soil at all, it only does so by compressing the high parts more than the low and somewhat flattening out any elevations.

Work of the "sohaga."

If the action of a "sohaga" be observed, it will be seen that it crushes clods to some extent, especially if weighted by labourers standing on it. This work, however, it does not do so efficiently as a roller. This is because the weight of the "sohaga" is spread over a large surface, and the pressure per square inch is small. Thus a "sohaga" weighing 100 lbs., and with two men weighing 100 lbs. each on it, *i. e.*, 300 lbs. in all, exerts a pressure $\frac{2}{3}$lb. per square inch only if the length is 7 feet and breadth 6 inches. A roller weighing 300 lbs. would be narrower, and the surface in touch with the soil would be probably $\frac{1}{5}$th or less than above, and hence more pressure per square inch would be applied. On the other hand, the "sohaga" does what the roller does not; for it definitely drags soil off the high parts of the land and leaves it in the lower parts. This action is very important on irrigated land which must be made as level as possible to allow of even irrigation; it also renders the "sohaga" a useful implement for covering seeds, even when these have been sown deep and the soil has not been subsequently harrowed. The "sohaga" then levels the land in a way that the roller does not; but it is not so effective in breaking clods as the roller; also it should be noted that owing to its being dragged straight forward instead of rolling, the "sohaga" could not be used if it were as heavy as a roller, and thus the effect of the "sohaga" in compressing the soil is not seen so far below the surface. Rolled land will be more solid below than similar land on which the "sohaga" has been used.

The wooden roller.

The wooden roller is commonly used in a few districts, *viz.*, Karnal, Rohtak, Muzaffargarh, and Dera Ghazi Khan.

Two main kinds of "sohagas" are used, *viz.*, a large type measuring $9' \times 1' \times \frac{1}{2}'$ and weighing about $2\frac{1}{2}$ maunds for two pairs, and a small kind measuring $6' \times 10'' \times 5''$ and weighing about

$1\frac{1}{2}$ maunds for one pair of bullocks. The large "sohaga" costs Rs. 14. It can cover 10 acres in one day of 10 hours.

Drills.

"Drills" for sowing seed in two or more rows at a time were until recently unknown in the Punjab, though they have been used for centuries in many parts of India.

Lyallpur drills.

They have been introduced to the Punjab by the Agricultural Department, and have been adopted by many farmers with very encouraging results. Two separate drills are made, one for kharif crops and one for rabi crops. The kharif drill (see fig. 9) differs from those used in other parts of India in the following respects :—

(*a*) Metal tubes are used instead of bamboo, and this applies also to the rabi drill.

(*b*) Metal cups are used instead of a wooden cup for the seed.

(*c*) A marker is attached to show the position of the next line.

As a rule a wide yoke 10 feet long is employed for using the kharif drill and in interculture. Such yokes are commonly used in Western India.

The sowing of cotton by means of the drill is strongly to be recommended. For, as will be seen later, cotton is a crop in which it is important to cultivate the land between the growing plants for several months. If the crop is sown broadcast, as it generally is in the Punjab, most of this work must be done by hand labour at great expense ; often it is not done at all. The seed can also be distributed much more evenly and at a more regular depth by means of these drills than is at all possible by broadcast sowing in the case of a thinly sown crop like cotton. The kharif drill sows two rows at a time either 3 feet apart for American cotton or 2 feet for country cotton. A marker is attached to the drill to make a line where the next row is to be sown. The method of working the drill is obvious, the depth of sowing is controlled by the angle at which the tines are inclined with the soil ; and this can be adjusted by altering the point of attachment on the pole or by means of the wedges fixing the tines into the beam. When the bullocks are trained to the work, one man only is needed to drop the seed and to turn the bullocks at the end of the row. In this province two men are usually employed, one to drop the seed and one to drive the bullocks. The drill should be worked straight up and down the fields, and not round and round as is usual with the country plough.

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KHARIF DRILL FOR AMERICAN COTTON

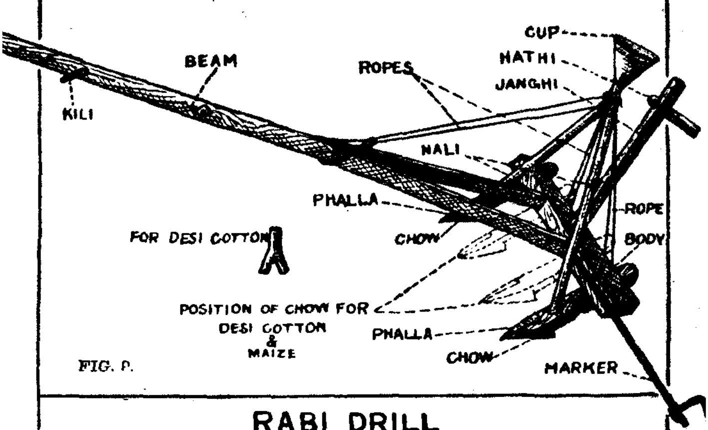
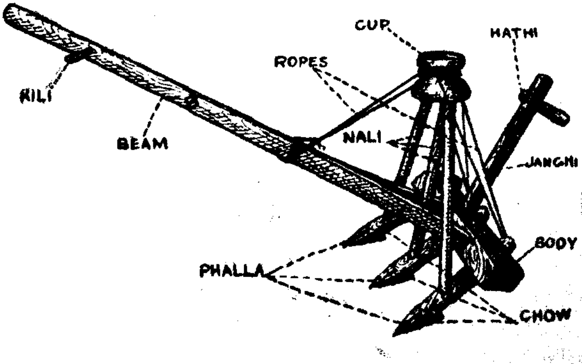


FIG. P.

RABI DRILL



The chief advantage of the "rabi" drill is in the saving of labour, as three rows are sown at a time instead of one, as in sowing by "kera" or "por." (See fig. 10.)

The rabi drill.

The cost of sowing an acre by these drills if two men are employed may be reckoned at about 6 or 7 annas in the case of American cotton and 7 annas in the case of country cotton or "rabi" crops.

These drills can be made by any ordinary artisans, and sample implements can be purchased from the Lyallpur Agricultural Station complete for Rs. 12 in the case of the kharif drill and Rs. 14 for the "rabi" drill; but they could perhaps be more cheaply made in the villages. Some hundreds of these drills have been so'd in the last few years.

In addition to using drills, crops can be sown in lines, at equal distance apart, by using a "marker" on the "munah" or "hal." (See fig. 1.) A large number of these markers have been sold, and the method is recommended for those on land not properly cleared, or where the labourers and cattle are untrained The marker is easy to attach to any "munah," and can be had at Lyallpur.

Plough and marker.

Labour during the harvesting season is much in demand, and wages run to Rs. 1-8 a day. It takes 5 men one full day to cut and tie an acre of wheat. A reaper can do at least 6 acres a day, using two pairs of bullocks and 8 men for clearing. It is better if 10 men are employed, so that cutting of the ends of fields and trimming of corners may be properly attended to. A reaper now costs Rs. 450, whereas it used to cost Rs. 250 only. The cost of cutting by hand and by reaper is given below :—

Reapers.

By hand.—Five men at 5 bundles giving 16 seers grain and 32 seers "bhusa" each. This comes to 80 seers grain and 160 acres "bhusa" valued at Rs. 4 and annas 8 a maund respectively = Rs. 10.

By reaper—		Rs.	a.	p.
Interest on Rs. 450 at 5 per cent	=	22	8	0
Depreciation 15 per cent.	=	67	8	0
Oil at Rs. 2 a day for 14 days	=	28	0	0
Repairs	=	25	0	0
8 men and 2 pairs cattle for 14 days at Rs. 14 per day.	=	196	0	0
(Men at Re. 1-8-0 and cattle at Re. 1, as no other pressing work to be done at that time).				
Total	=	339	0	0

Assuming 80 acres cut per season, cost comes to Rs. 4-4 per acre as compared to Rs. 10 by hand labour. If 60 acres only is cut, the cost comes to Rs. 5-12-0 per acre, assuming 14 days' work.

The reaper recommended for the Punjab is the Rajah manufactured by John Wallace & Co. of Glasgow. It is higher geared than a home reaper, and is adopted for cutting while passing over irrigation *bunds*. Two men operate it, one driving the bullocks and one working the tilting board. In practice much time is wasted owing to the fields not being cleared some time before the reaper is to start work. In long fields it is best not to cut at the ends, but to cut along the two sides only. A self-delivery reaper is said to be working successfully on one or two estates in the Lower Bari Doab Canal Colony, but owing to their more complicated nature they are not recommended by the Department of Agriculture as yet. Serrated knives, which require no sharpening, are more satisfactory than the ordinary knives used.

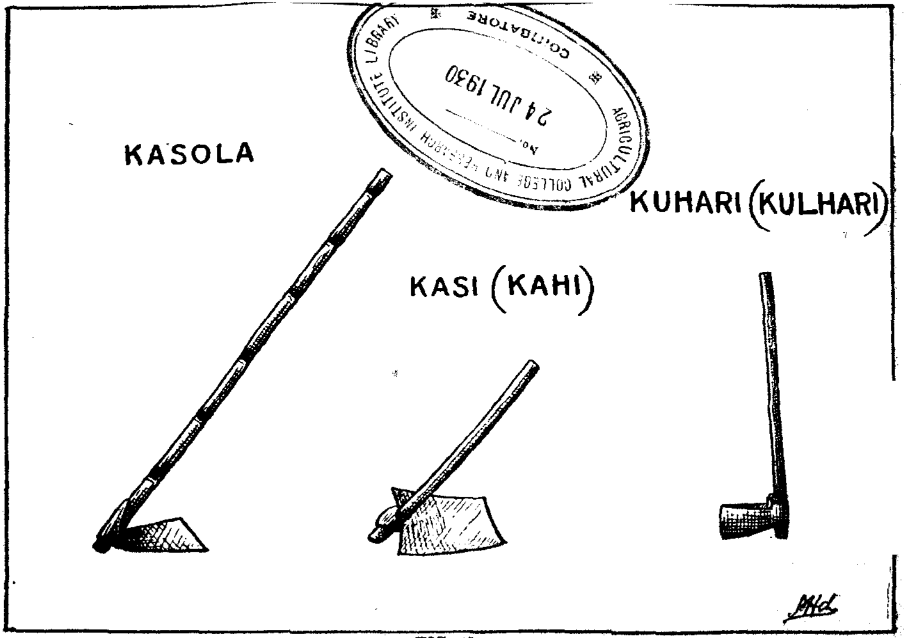
Winnowing Machines.—Several types have been tried. As a rule the demand for winnowers is slack, and only occurs in exceptional years. The zemindar winnower is recommended for cleaning grain from weevils and for cleaning grain before sowing.

**Threshers.*—The best type as far as getting good "bhusa" and undamaged grain is concerned is "Ransomes." See chapter X on wheat for details of cost of threshing. A new small type is expected out shortly for trial. The bigger threshers are unsuitable for moving about from village to village along bad roads.

The following is a list with approximate costs of the othe small implements in use by a small zemindar :—

		Rs.	a.	p.
(1)	Karah or leveller (worked with 4 bullocks.)	10	0	0
(2)	Panjali or yoke, long ...	6	0	0
	Do. do. small ...	4	0	C
(3)	Jandra or ridging-rake ...	1	0	0
(4)	Sanga or wooden fork ...	1	0	0
(5)	Tangli or five to seven-pronged fork.	2	0	0
(6)	Toka or fodder-cutter ...	1	0	0
(7)	Gandala or hole digger ...	1	0	0
(8)	Koharee (khulhari) or axe ...	2	0	0
(9)	Kasi (kahi) or spade ...	4	0	0
(10)	Kasola or small spade ...	2	0	0
(11)	Ramba (khurpa) or hand-hoe ...	0	12	0
(12)	Baguri (used for "anhi godi") ...	0	12	0
(13)	Dranti (datri) or sickle ...	0	8	0
(14)	Pilchhi datri or cane sickle ...	0	8	0

* See "Agricultural Journal of India," Volume X, Part III, page 285.



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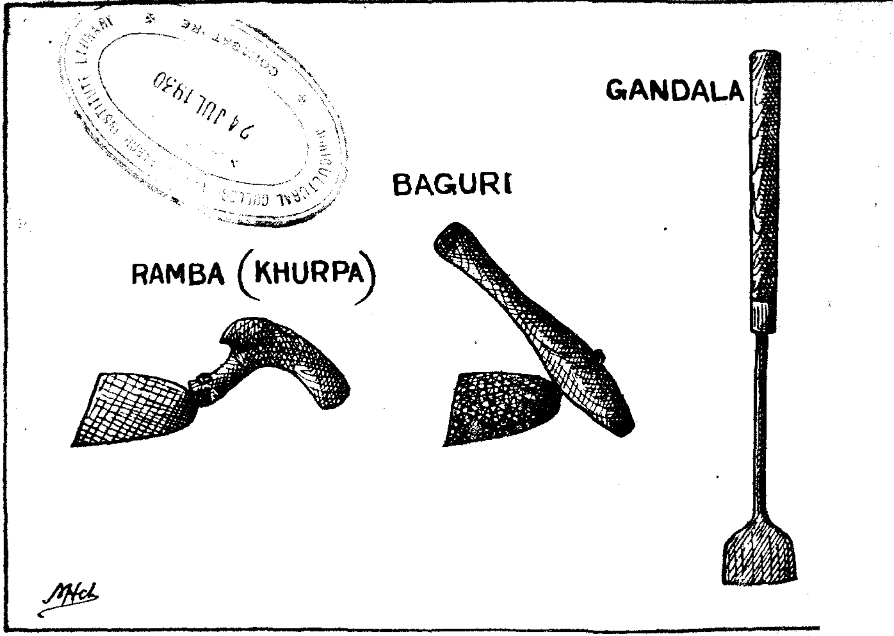

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FIG. 13.

CHAPTER VI.—ROTATION, FALLOWING, AND MANURING.

These three are inter-connected and cannot be discussed' completely apart from one another or from the main character of the agriculture of the tract, *i.e*, whether "nahri" (canal)," chahi' (well), or "barani" (rain) cultivation is prevalent. It is necessary, however, for the sake of clearness to attempt to discuss them separately.'

Rotation.—The practice of growing different crops in rotation on a piece of land, as apart from growing the same crop year after year, has been known and practised in India from time immemorial. Except near large towns, where vegetables and intensive farming are followed on a limited scale, the general type of farming is very uniform all over the Punjab. The main differences that are found are in the main connected with the supply of water. Other factors, such as (*a*) physical condition of the soil, (*b*) prevalence of weeds, and (*c*) supply of plant food, are, though very important in themselves, of secondary importance here.

Water supply.

In perennial canal-irrigated land the conditions generally are that the winter supply, though generally smaller than the summer supply, will go twice as far on the land, as evaporation is small in winter and the number of irrigations per crop is only one-half of what it is in summer. This means that with present supplies the rabi cropping must be generally twice as heavy as the kharif. Wheat is the most profitable rabi crop, and hence it finds a place in almost every rotation in canal land. Again water is supplied to cultivators in Punjab canals on the assumption that 66 per cent., or in some cases 75 per cent., of the land will be cropped annually. In practice the cultivator manages to do 100 per cent. intensity instead of 75 per cent. as originally provided for. To ensure this intensity it has been necessary to restrict crops requiring much moisture, such as sugarcane, "senji,' maize, and also rice, except in kharif channels. These being the basic conditions, we can

Canal tracts.

proceed to consider rotations in vogue on the Lower Chenab Canal. (See Chapter IX).

1.	Wheat, "toria," cotton ...	3 crops in 3 years.
2.	Wheat, wheat, "toria," cotton ...	4 crops in 4 years.
3.	Wheat, maize, "senji," cotton ...	4 crops in 3 years.
4.	Maize, "senji," cotton ...	3 crops in 2 years.
5.	Wheat, maize, "senji," sugarcane	4 crops in 3 years.
6.	"Chari-guara" (mixture), gram, *cotton.*	3 crops in 2 years.
7.	Wheat, cotton ...	2 crops in 2 years.
8.	Gram and wheat ...	2 crops in 2 years.

Some wheat follows wheat, and gram follows gram in certain areas annually.

The areas of different crops grown commonly on 25 acres of canal land are as follows:—

Cotton	...	4 or 5 acres.
Sugarcane	...	1 acre. In some villages this is not grown at all.
"Chari-guara"	...	3 acres of crop or 2 acres of land, as one acre will generally carry "gram" crop in following rabi or two successive crops of "chari-guara."
Maize	...	1 or 2 acres. Generally only 1 acre
"Toria"	...	3 acres. Fairly constant.
Wheat	...	11 or 12 acres. Very regular.
"Senji"	...	1 or 1½ acres.
Gram	...	1 acre or more where command poor.
Miscellaneous fodders, turnips, etc.		½ or 1 acre; this may include turnips, melons, onions, potatoes, sannhemp etc.
Total	...	25½ to 28½ acres.

As will be seen this gives an intensity of cropping of over 100 per cent., which is the case on the average for the whole of the Lower Chenab Canal Colony.

Wheat, which occupies much the greatest area, finds a place in practically every rotation. "Toria," which usually follows wheat, after a fallow of 4 or 5 months is itself followed invariably by cotton, but as the area of cotton is greater than that of "toria," cotton is also sown after other crops. It sometimes follows "senji," which has been sown in the "vadh" of maize, and in that case, being on good land generally, gives a very heavy crop

Some cotton also follows wheat, though this is known to be bad practice, as there is in that case very little time for cultivation. The wheat is harvested in latter half of April, and the land ploughed and cotton sown almost immediately. Gram is sown in high land, where, owing to the difficulty of watering, a crop is required which can thrive on almost one watering ; it is also sown after "chari" with very little preparation of the soil. Where much gram is sown it is generally an indication of poor water supply or a high proportion of light land. "Senji" is often sown in standing cotton or maize at the end of September or early October. It thus benefits from late waterings of these crops, and is regarded when sown in maize as a good preparation for sugarcane. The preceding maize is heavily manured in such cases, as sugarcane is rarely directly manured. In villages where the water supply is very good, cotton often follows sugarcane ; but this is not common, as the preparation of the land after cane is laborious, and the stumps and roots of cane take a good while to decay.

It will be seen that the whole of the farm is never all under the same simple rotation. Any such general rotation is practically impossible on account of the small area under summer crops and the necessity for keeping part of the land always in high condition for these crops. This can only be done by concentrating all the available manure on the area where these are grown. But some of the fields are kept more or less permanently *under one rotation and others under another, the rotations being* dictated by the times of sowing and the condition in which the soil needs to be for the different crops.

The whole system is in the main adapted to suit the water supply from the canal. The local climate and the relative profitableness of the various crops have a secondary influence only.

In the Lower Jhelum Colony the crops and rotations are similar to those of the Lower Chenab, although in the former the rabi supplies in the canal have been practically equal to the kharif so far.

* The utilized supply of the Lower Jhelum Canal and the Lower Chenab Canal for kharif and rabi are in the former 1 : 1·1 and in the latter 1 : 1·3. In the Lower Bari Doab Canal the proportion is still wider, but as the canal is developing and the latest figures are not available, it is not possible to give actual

* Note by H. W. Nicholson, page 18 m., "Punjab Engineering Congress Report," 1918.

ratio here. The proportion of cotton in the Lower Bari is very high, being often 8 acres per square, though the average comes to 5 acres. Comparatively little "toria" has so far been grown on this canal, though there are indications that more will be grown in future.

In canal areas on the eastern side of the Province the cropping is affected by rainfall and by the fact that in many localities cotton does not flourish as well as in the western part of the Province. More maize and sugarcane are grown than in the dry tracts.

"Barani" tracts.

As the great bulk of the rain comes between mid-July and middle of September one would except kharif crops to be mostly grown in "barani" (or rain tracts). This, however, is not the case. A rabi crop such as wheat can be matured on about ⅔rd or half of the water required for say cotton, and hence the kharif rains if conserved in the upper soil by cultivation are more certain of producing a rabi crop sown in the following autumn than of producing a kharif crop. Summer crops require water more frequently, and are less able to withstand drought owing to the rate of transpiration being more rapid than is the case with rabi crops. Again it should be noted that the Punjab gets some winter rains, which rarely fail from December to February, which thus help in maturing the rabi crops. It is essentially a question of security, therefore, that influences the Punjab farmer to prefer rabi crops to kharif crops. It should also be noted that the rabi crops are more marketable and better money crops than the kharif, with the exception of cotton. As regards the latter, it should be observed that as the rains come very late and stop somewhat early in September, the season is too short for cotton in these tracts. This accounts for the fact that only 15 per cent. of the Punjab cotton crop is grown under "barani" conditions.

Economy of rabi season only apparent.

It may be well to correct any possible misinterpretation of the above remarks as indicating that the rabi season is a more efficient growing period than the kharif. This is far from being the case. * Measurements of the transpiration ratio of kharif crops such as maize or millets, and rabi crops such as wheat, indicate that the former produce a pound of dry matter with much less expenditure of water. Leather in Memoir No. 8, Vol. I, page 179, from work at Pusa, shows that wheat transpired from 550 to 850 lbs. of water for every pound of dry matter produced, whereas maize transpired from 330 to 450 lbs. or "juar" (Chari) 400 lbs. only.

* See King's Books and Leather's Memoirs.

As a practical instance it may be noted that an acre of "chari-guara" mixture grown as fodder and sown at Lyallpur in July and harvested 10 weeks later, though only receiving 4 irrigations, may produce 10 tons of green fodder, whereas "senji," which occupies the ground from October to March, *i.e.* 5 months, and receives five or six waterings, only produces on the average 6 tons. There is no doubt that the kharif season is an extremely active growing period, and only the supply of water available limits its more extensive use for crop growing.

Rotations in "barani" tracts.

A frequent practice in "barani" tracts is to grow a rabi crop followed immediately by a kharif, and then one year's fallow. The reverse, *viz.* growing a kharif crop followed by a rabi, would be impracticable, as will be clear from a study of the principles enunciated above. This latter practice is, however, rather prevalent in irrigated tracts with only a kharif supply, as the succeeding rabi can generally be matured on the first watering given at the end of the kharif either after or before the harvesting of the kharif crop. It is interesting to note that cultivators on kharif channels frequently claim that no charge should be made for rabi water in such cases, as no actual irrigation is done in that season. The fact, however, that this practice is only possible when kharif irrigation is available, and that it is not possible in purely "barani" tracts, is a sufficient answer to the claim.

Common rotation on "barani" land.

Wheat, gram or barley in the rabi, followed in the succeeding kharif with "chari," "moth," "mash," "til" or cotton with a year's fallow, is a common practice in "barani" tracts. Again sometimes a kharif crop is grown and the land left fallow for the succeeding rabi, and then cropped again in the kharif. This is not so common as growing rabi crops only with a kharif fallow. The latter practice is sound in that a kharif fallow enables the soil to recover much more quickly than in a similar length of fallows in the rabi. As labour is one of the main considerations of a farmer, it is necessary that he should arrange his cropping to provide as far as possible work for the whole year, and hence a system of kharif cropping only or rabi cropping only would be uneconomical from that point of view. A feature of all "barani" land is that the farming is always extensive, and cropping rarely attains 100 per cent., and very seldom exceeds this. In canals the farming is a mixture of intensive farming on a small area and extensive cultivation in the main as the supply of water allotted prevents anything else. On wells, on the other hand, an intensive system of frequent cropping is common. As the rapid cultivation of land after rain is desirable, especially in "barani" tracts, there would appear to be a grear

future for implements like the bar-harrow and drag-harrows, which cover three or four times as much land as the "deshi" plough, and thus conserve the vital soil moisture so essential to success in "barani" cultivation.

Mixture.

In addition to rotating crops, the practice of growing "mixtures" is prevalent throughout the Punjab, especially in "barani" tracts. Common mixtures seen are the following :—Barley and gram (called "goji"), wheat and gram (called "berra"), wheat and barley, "sarson" and wheat, "toria" and gram, "til" and cotton, "moth" and cotton, melons and cotton, "senji" and cotton, "juar" (chari) and "guara," "chari" and "moth," maize and "senji," etc. In the main the reason for such mixtures is that they form a kind of insurance against the vagaries of the season. Thus gram and wheat are a typical example of such a mixture. If the season is favourable as regards moisture, the wheat will produce a good crop, whereas in a dry year the gram may at least be expected to give a fair yield. This mixture has the additional advantage of one of the crops, gram, being a legume, and thus able to enrich the soil in nitrogen. A similar reason accounts for barley and gram. though barley itself is fairly draught resisting. Again barley and wheat mixture, so common towards Ferozepore side, is an example of provision against a dry season. It is interesting to note that these three mixtures are now rarely seen in canal lands, where such insurance is not necessary, and the extra labour involved would be a serious factor. Even in canal land partial mixtures are, however, common. Thus a sprinkling of "sarson" is often grown in wheat, the former being removed in January or early February before the wheat has reached its maximum demands on the soil. Similarly melons and "moth" are grown with cotton and removed from May to July before the cotton shades the ground. In the former case the land is also heavily manured. Not more than 10 per cent. of the cotton grown by good cultivators has these two mixtures in, as they interfere with interculture and are not looked upon with favour. Again the sowing of "senji" in the "vadh" of growing cotton in early October or in maize at the same time is a common practice in canal land, and applies to a third or so of the cotton and maize area. The "senji" is protected in the early stages by the shade of the parent crop, and the water it receives helps in the maturing of the cotton or maize. Another mixture which has become very common of late is "guara" and "chari". The former alone does not make a good fodder, but mixed with "chari" not only enriches the land, but as a rule very heavy crops are obtained in this way without unduly impoverishing the soil, as would be the case if "chari" alone were

grown. The mixtures "til" and cotton, and "chari" and "moth" are generally only seen in "barani" tracts.

Well lands.

As in canal and "barani" lands, water is the governing factor here also. It is, however, the cost of water that tells in well cultivation. A well 35 feet deep, and giving one-tenth of a cusec of water, will irrigate an acre 2 inches deep in two days of 10 hours at a cost of Rs. 3. Waterings are more frequent on well cultivation than on canal land, though the quantity given per irrigation is less. Hence wheat on well land gets 4 or 5 irrigations at a total cost, allowing for repairs and depreciation, of about Rs. 16 as compared to Rs. 4 charged in canal areas. This fact accounts for the high intensity of cultivation in well lands, as by having crops near the well there is less loss by percolation. Rabi crops are favoured, as more can be kept going with the limited supply of water than in the kharif. Where a town is near vegetables are favoured, and follow one another in rapid succession on the same land. Manure is given in plenty if available, as fallowing, except for very short periods, is impracticable.

Varieties.

In all classes of land the crops grown are invariably very mixed as far as different types of the same crop are concerned. Thus a "deshi" cotton field contains invariably 5 or 6 different kinds of cotton differing in ginning percentage, yield, and water requirements. Similary wheat and "toria" generally contain at least 5 or 6 different varieties, all differing in yielding capacity. There is nothing to be said in favour of these mixtures, and much useful work has already been done by the Agricultural Department in substituting pure high yielding types in place of the mixtures generally grown. This matter is discussed more fully in the chapters on various crops.

Fallowing.

What has been said above will indicate the conditions where fallowing is prevalent. It is very general in "barani" tracts, and also, but to a less extent, in canal land. As will be seen fallowing allows the land to recover its fertility and to accumulate some nitrogen from the air, thus being partly a substitute for manuring. Manuring is little favoured in dry "barani" tracts, as generally sufficient moisture is not available to decompose the manure.*

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* See "Manuring in the Punjab" by W. Roberts.

Green manuring.

This consists in growing a green crop, generally a legume, and ploughing it into the field when it is in flower. The crops most commonly used are sann-hemp and "guara," and recent experience indicates the latter as preferable. The practice is rare, and though no "water-rate" is charged for crops so grown by the Irrigation Department, it has not extended even in canal colonies, and is not likely to do so as long as the water supply is only sufficient for 100 per cent. intensity of cultivation.

It must be remembered that a crop of "guara" is worth at least Rs. 40 as a fodder, and hence ploughing it in means an expenditure of a large sum per acre on manure.*

Practically the only manure used extensively is farmyard manure. As cowdung is the main source of fuel, a proportion only is available for manuring, as cow dung cakes are used universally as fuel.

In canal areas generally a third of the whole quantity is available, and is applied mainly to maize, vegetables, and melons. Sometimes cotton, sugarcane, or wheat are manured, but comparatively rarely.

Assuming ten head of cattle to be kept per square of 25 acres, we may calculate as follows :—

Each head excretes 30 lbs. or 300 for whole number. If one-third of this is available, it comes to 36,500 lbs. in one year, or roughly 18 tons, or sufficient to give over 5 tons per acre to 3 acres annually and to cover the square once every eight years.

In "barani" tracts with a small rainfall little manure is used, as it is said to dry the land. Manure is plentifully used if available wherever the rainfall is sufficient or where irrigation is feasible.

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* Article in "Agricultural Journal of India" for October 1913 on "Green Manuring and Hot Weather Cultivation in the Punjab."

CHAPTER VII.—IRRIGATION.

Introductory.

As pointed out already, out of a total cropped area of 27,000,000 acres, 12,200,000 acres is irrigated or 45 per cent. Of the irrigated area 8,000,000 acres is done by Government canals, 500,000 acres by private canals, 200,000 acres by tanks and other sources, and 3,500,000 acres from wells.*

Well irrigation.

Irrigation from wells has proceeded from time immemorial. It is estimated that there are 290,000 wells in the Punjab.† These are mostly found in the sub-montane tracts where canal irrigation is not available. A well with water level at 35 feet from the surface costs nowadays, about Rs. 1,000, assuming that the depth is 15 feet below the water surface. The capital represented by wells, assuming this average cost, is therefore 29 crores As a rule well-irrigation is not practised where the depth of water is much over 35 feet, as the cost of lifting beyond that becomes excessive in comparison to the value of the crops. In tracts like Gurgaon, however, the wells are generally 50 to 60 feet deep, and are extensively used for rabi waterings for barley. That tract, however, has a fairly secure rainfall, and wells merely supplement the rain, and crops generally get two well irrigations as compared to four or five in districts like Jullundur and Sialkot. Under such circumstances it pays to lift the water from much greater depth than is usually considered profitable.

Waterlifts.

Persian Wheel.—Irrigation from wells is in the main carried out by means of the Persian wheel (rahat). The latter consists of a large drum (bair), over which passes an endless rope ladder (mahl) with buckets attached to it at distances of one or two feet. The rope-ladder with buckets reaches below the surface of the water in the well. The drum with the buckets is revolved by means of a simple round-about gear worked by a pair of bullocks. The lever to which the bullocks are yoked gives motion to a horizontal toothed disc (chakal), which through the medium of a rude cog-wheel (chakli) turns the drum. The buckets are generally earthenware vessels holding from $1\frac{1}{2}$ to 2 seers water. Some simple

* Statistics of India (Agricultural), 1916 17.
† Season and Crops Report, Punjab.

mechanical deductions as regards the output and work of the Persian Wheel may be laid down. These are as follows :—

(1) Increase in the size and number of buckets increases draft and discharge.

(2) Increasing the size of the "bair" increases the velocity, draft, and output; whereas decrease has the reverse effect.

(3) Altering the relative gears of the "chakal" and "chakli" affects output and draft. Increase of number of teeth in the "chakal" increases draft and output, and *vice versa.*

(4) The larger the circle through which the bullocks move the less the draft and the output.

It will be seen from above that the Persian Wheel is very flexible, and adapted for this reason for any depth of well. In the ordinary form of Persian Wheel the bullock track is round the well. Sometimes it is on one side, as in the case of the "jhallar" used for lifting water from streams or tanks.

The Persian Wheel varies in detail from place to place. Th rope is generally made from hemp, but it sometime is made o date-palm fibre, and in Jullundur sugarcane stalks, after passing through the wooden crushing mill, are used. This wooden mill is still retained mainly for this reason. In other parts of the Province the iron mill is almost universally employed. Instead of rope an iron ladder is sometimes used. The buckets are also often made of iron. The whole machine is sometimes made in iron. and before the war these were becoming very popular in Ludhiana. Various improvements have been tried, such as using roller or ball bearings, but none of these have so far been a widespread success. The wooden machine used to cost about Rs. 100 ; it now costs Rs. 150 or more. It gives a supply from a depth of 35 feet of about $\frac{1}{12}$ cusec. One man only is required to attend to the machine, and if he has work near by, only occasional attention is necessary in case the cattle stop.

The Charsa (*Ramiokos*).—This is in common use in Gurgaon, Delhi, Rohtak, and Ludhiana. It consists of a whole bullock hide, with the corners cut off, and tied by leather thongs to an iron ring 18 to 24 inches in diameter. It holds from 24 to 42 gallons of water. The bag is pulled up by a pair of oxen by means of a rope passing over a pulley at the top of the well, and attached to the bucket and to the yoke of the oxen. The cattle walk down an inclined plane, and this tends to even the work, as the cattle have to climb up without a load. On the bag reaching the level of the discharging trough, it is emptied by an attendant

stationed there for the purpose. The emptying of the bag is facilitated by the driver jerking the rope on receiving a signal from the man at the well. The toggle or "kili," attaching the rope to the yoke, is detached and the bag thrown into the well, where it descends by its own weight. The bullocks turn round and walk up the incline for the next load. Sometimes two pairs are used, and in that case three men are employed instead of two. The following are details of the working of a "charsa" at Rewari. Depth of well was 63 feet The volume of the bag was decreased in this case by inserting a piece of wood 18 inches long on the outside under the ring, and thus flattening one side. The capacity was 18 gallons. Six buckets came up in four minutes ; hence in 8 hours the water raised was $\frac{90 \times 8 \times 18 \times 1}{2{,}240}$ = 58 tons, or say 2 inches over 2 "kanals" in a day of 8 hours.

The Self-Delivery or Sundhio Kos.—This is a self-discharging "charsa." It consists of a leather tube which may vary in length from 6 to 10 feet. One-half of the tube is wider than the other half, and is distended by an iron ring at the mouth. The other end is not distended. The wide half is 18 inches to 2 feet in diameter. The ring and bar is the same as in the Ramio. A stout rope is attached at the intersection of these bars. The other end of this rope is passed over a pulley fixed almost directly above the lip of the receiving trough and about 4 feet above the top of the well. A second thinner rope is fastened to the smaller mouth of the leather bucket in a manner which will not obstruct the flow of water through the small mouth. The other end of the thin rope is passed over a roller which works on the lip of the receiving trough. These two ropes are attached to the neck-yoke of a pair of bullocks, and their lengths are adjusted so that the narrow half of the bucket doubles up alongside the broad half and the two mouths of the leather tube are level with each other as the bucket ascends or descends in the well. When the bucket reaches the top of the well, the narrow mouth follows its own rope over the roller and delivers the water into a receiving trough, whilst the broad mouth is by means of its rope carried to the pulley 4 feet higher up. This ensures that the bag is completely emptied of water. Bullocks walk down an incline as in the Ramiokos, but instead of being detached they back to point of starting instead of turning round. For this work good moving active bullocks are used—heavy animals are unsuitable. The outlet from the receiving trough is sufficiently large to allow the trough to empty itself as fast as it is filled, and small enough to keep up a continuous flow in the channel which it feeds.

This lift is used for wells of moderate depths, *i.e.*, below 35 feet.

This lift is unknown in the Punjab, but is extensively used in Western India. It has the advantage of saving the labour of one man, and is very suitable where depth does not exceed 30 to 35 feet.

The Double Mote.—Bullocks walk in a circle. Two bags are attached by a winding rope to a drum, one unwinds while the other winds up. The drum is on a vertical axis, and ropes pass over pulleys on the rim of the well. This method is not to be recommended, as cattle walk on a level and get no benefit from their weight as they do in case of ordinary "charsa" when walking down an inclined plane. This lift is not in general use anywhere in India.

Dhenkli or Counterpoise Lift.—This consists of leather stretched upon a boat-shaped frame suspended by a rope to the end of a horizontal pole, which is carried and evenly balanced on a stout upright support, on which it works see-saw fashion.

It is used for lifts up to 5 or 6 feet to lift water from tanks from one channel to another. Generally the narrower end of boat rests on the edge of delivery channel, and is attached there by means of a through-pin which acts as a hinge.

The counterpoise is of such weight that no great exertion by manual power is required to depress the lift when empty or raise it when full. It can be worked by one man. There are various forms of this lift requiring one or two or more men.

Egyptian Screw.—This is largely used by the "fellah" or Egyptian cultivator. It consists of a cylinder of wood about 15 inches *in diameter and 3 to 5* feet long, inside which is a series of planks arranged in the form of a screw. At each end of the cylinder is an axle, and this rests on two supports, one in the water and one by the delivery trough. The cylinder is turned round like a turbine, and the water rushes through. A slope of 35° to 45° is generally employed for the cylinder to facilitate the raising of water. This is useful for shallow depths up to 2 or 3 feet. It can be made for about Rs. 30.

Basket Lift or Jhil Lift.—This consists of a shovel like scoop and is swung by two men. Each swing catches some water and lifts it, say 1 to 3 feet high, to an upper channel. Sometimes the basket is suspended from a tripod, but this is not essential.

Baldeo Balti.—Two boat, shaped buckets of iron are attached in the same way as the boat in the counter-poise lift. The ropes are attached at equi-distant points from the fulcrum of a pole turned round by bullocks. The boats come up alternately. It is used for lifts up to 5 feet.

Chain Pump.—This is on a somewhat similar principle to the Persian Wheel. A pulley is keyed on to a shaft which gets motion, either by a handle, when manual labour is employed, or by a roundabout gear, when bullock power is used. This pulley carries on it an endless chain. The chain, having discs on it at intervals of a foot, is made to ascend through a tube which descends from the top of the well to 2 feet below surface of water. The discs are about the same diameter as the tube. In the improved pattern leather washers are used strengthened by iron discs. The volume of water is in ratio to the size of the tube. The discs on the chain fit into corresponding notches on the pulley; therefore it does not slip back. Two or more tubes could be put on the same shaft. A chain pump with 4 inches pipe will lift 2,500 gallons per hour from a depth of 20 feet.

This pump does not work well at depths over 20 feet because of the increase of friction and loss of water by drainage along edges of discs.

Oil Engine.—Where supply of water is abundant, this may be used. For this purpose a centrifugal pump is generally employed. The well should be capable of giving at least ½ cusec or 10,000 gallons per hour to justify putting in an oil engine. Most wells in the Punjab would suffer from "blowing" if water was pumped to this extent from them. To correct this, where a large supply of water is required, a form of well known as the "Tube Well" may be installed.

Tube wells.

The "Tube Well" consists essentially of a copper mesh supported on a strong iron frame. This is inserted in the soil so as to reach several feet below soil water level. The upper part of the tube consists of a plain iron pipe. With a "Tube Well" supplies up to 3 or more cusecs can be obtained by having a sufficiently wide pipe, put into the requisite depth of water bearing strata. A fairly large number of "Tube Wells" have been put down during the last few years, especially in the United Provinces. These installations are expensive and require skilled labour for the preliminary boring and putting down of pipes; but they are gradually extending in popularity.

A good deal has been done in recent years in increasing the supply of ordinary wells by boring so as to reach lower water bearing strata. A plain, or, better still, a tube well pipe, is put in the bore. Water generally rises to the level of the previous water table or higher by its own pressure. Well boring is very successful in several parts of the Eastern Punjab. This increased supply is artesian. Purely artesian wells are rare in the Punjab; but there are a few successful ones, and possibly many more could be discovered if experiments were systematically carried out. One such well at Rawalpindi gives a supply above surface level from a bore over 200 feet down.

Increasing supply of ordinary wells by boring.

An ordinary Persian Wheel working a well 30 to 35 feet deep will give generally $\frac{1}{10}$th or $\frac{1}{11}$ cusec supply. To irrigate an acre to the depth of two inches only would require 24 hours or 3 days of 8 hours each. If we value a man and one pair of bullocks at Re. 1-8-0 a day, this comes to Rs. 4-8-0 per irrigation. As 2 inches depth is only about $\frac{2}{3}$rd of that generally given on canal lands, it is customary to irrigate more often from wells. Thus wheat on "chahi" requires 4 or 5 irrigations *after sowing as compared to 3 in canal land.* The cost, assuming "rauni" and subsequent irrigations to number five, comes to Rs. 22-8-0. To this must be added cost of maintenance of the well and water lift and interest on the capital cost of the well. It may be argued that the cattle and man cost less than Rs. 1-8-0 a day, but even taking the very low figure of Re. 1 a day, the cost of wheat irrigation comes to Rs. 15 per acre in labour alone. The following is an attempt to make an estimate of the cost per crop of wel irrigation :—

Cost of lifting water from wells.

Assuming the well commands from 12 to 15 acres, and that an *average of 20 crops are grown,* we may *calculate* as *fol-lows* :—

		Rs.	a.	p.
Capital cost of well Rs. 1,000...	Interest at Rs. 8 per cent....	80	0	0
Persian wheel Rs. 150	... Interest and repairs at Rs. 12 per cent.	18	0	0
	Total ...	98	0	0
Say a total of Rs. 100 per annum or Rs. 5 per crop ...		5	0	0
Cost of lifting water, assuming Re. 1-4-0 per day for a pair of cattle and one man, for five irrigations ...		18	12	0
	Total	23	12	0

The actual number of crops irrigated by a well will depend on the rainfall; in some cases a much larger number than 20 acres can be given one or more irrigations Again, if much sugarcane is grown, the number will be less than 20 acres.

It may be confidently stated that if water can be raised at a cost of less than Rs. 20 per acre, there is a wide prospect for extension of "Tube Well" installation.

Canal irrigation.

The main perennial canals have been referred to in Chapter I The canals are of vast economic significance in the Province. Thus taking the wheat crop alone, 33 per cent.* of the area is grown under canal irrigations; and 66 per cent. of the whole of the irrigated wheat is grown under canal irrigation.

The details for any particular canal can be had from the Annual Administration Reports of the Irrigation Department. In general the perennial canals take off from the rivers above "pucca" Head Works constructed at a point up the river, which will give ample command over the area to be irrigated. The main canals and larger branches follow the ridges or high ground in the plains as far as possible. During the summer season the canals generally run full, but in winter, owing to shortage of supply, the various branches and distributaries run in rotation. The adjustment of supplies in the five linked canals, *viz.*, the Upper and Lower Jhelum, Upper and Lower Chenab, and the Lower Bari Doab, is fixed by the Chief Engineer in consultation with the Superintending Engineers.

The latter arrange the supplies of the branches and distributaries of their respective canals in consultation with the Executive Engineers. In the newer canals, *e.g.*, the Lower Chenab, the land is divided into rectangles containing 25 units, which may be a "killa" (1·1 acres approximately) or 1 acre as in the Lower Bari Doab Canal. A rectangle or square thus measures 27·8 acres on the Lower Chenab Canal and 25 acres on the Lower Bari Doab Canal. A number of rectangles, varying from 30 to 70, forms what is known as a "chak". Many "chaks" have 2 villages. Usually a separate outlet is given for an area of 20 to 30 squares. Thus a "chak" has often 2 or more outlets with supplies varying from 1½ to 3 cusecs. Usually a supply of one cusec (cubic foot per second) is allotted at outlet head for 275 acres, or what corresponds to 10 squares on the Lower Chenab Canal and 11 squares on the Lower Bari Doab Canal.

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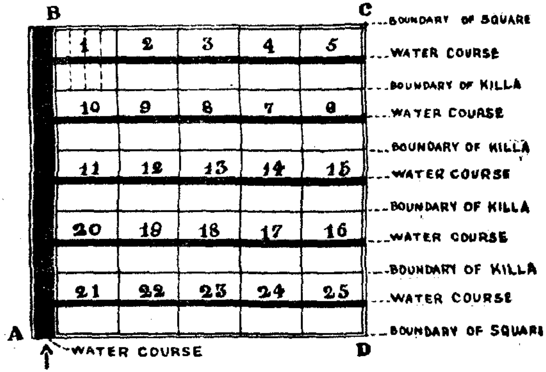
* Administration Report, Punjab Irrigation, 1916-17.

The management of the water after it leaves the distributary into the zemindar watercourse is in the hands of the village authorities. Each square gets so many "pahars" (3 hours supply of water) as will enable the turn (wari) to be finished in 10 to 14 days. If the supply is, say, 2 cusecs for 20 squares, then each square can get 4 "pahars" in every turn or "wari" of 10 days, or six "pahars" if the "wari" is 15 days.

To facilitate distribution and economise water, each "killa" or acre is divided into a number of compartments (kiaris). According to Canal Regulations this number is supposed to be 8. As one cusec will irrigate an acre in one "pahar," each "kiari" takes between 20 and 25 minutes. With a supply of two cusecs the time is halved, and it is in that case difficult to control the water if 8 "kiaris" are maintained. The zemindar usually arranges matters, so that he has 20 minutes to half an hour for each "kiari." This figure of 8 "kiaris" per "killa" is therefore suitable for supplies below 1½ cusecs; above that a smaller number should suffice. It must be remembered that the cutting of the bank of the watercourse in 8 different places to irrigate an acre entails much labour, and tends to weaken the banks and cause leakings, especially when the supply is considerable. The plan of a square and its watercourses is shown in Fig. 15.

PLAN OF A SQUARE IN THE CANAL COLONIES



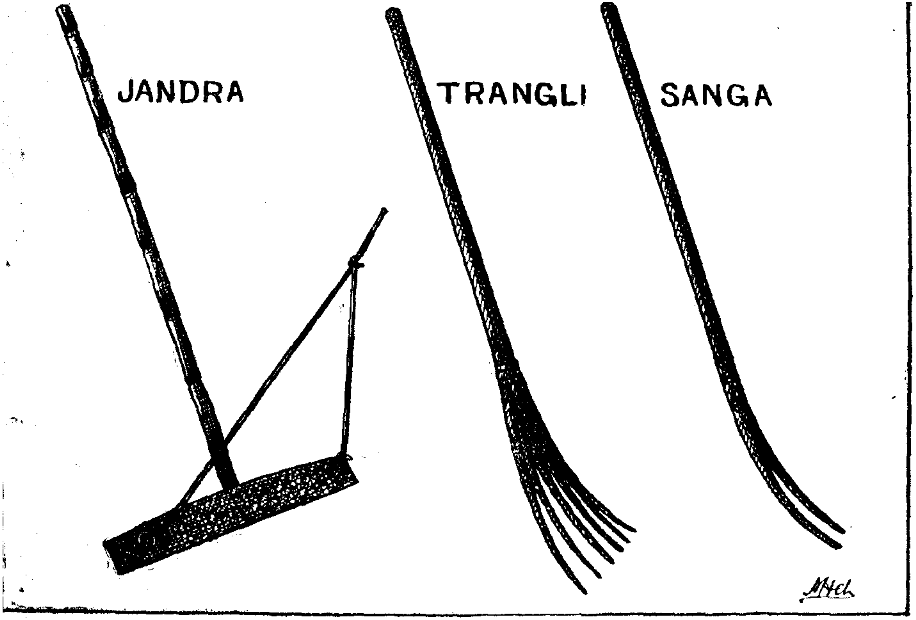


FIG. 11.

If water comes from direction A B, the first "killa" to be watered would be No. 21, and after that 22, 23, 24, 25, and then 20, 19, etc., the last to be watered being No. 5 if the whole square is to be irrigated. It will be seen from the above diagram that the watercourse traverses the middle of each "killa." If 8 "kiaris" are made in each "killa" there will be four on each side of the watercourse. "Killa" No. 1 has been divided accordingly. Frequently, while conforming to regulations as regards number of "kiaris," the zemindars irrigate one from the other, and may, for instance, only make two openings from each bank instead of four. This is much more wasteful of water than if only 4 "kiaris" or plots had been made from the beginning. The "kiari bunds" are made as a rule after sowing by means of the "jandra," for which two men are employed (see Fig. 11).

Water is charged for on an acreage basis. A schedule of rates is fixed for each class of crops on each canal. These rates vary from one or two rupees to seven rupees in case of crops like sugarcane. Five or six classes, or schedules of rates, are generally in force in each canal. The actual charge is so small compared to the value of the crop that this factor has practically no influence on the cropping followed. The total of water rate, land revenue, and "cess" per acre of cropped area ranges from Rs. 8 to Rs. 10 generally, whereas the gross value of the crop may range from Rs. 80 in case of wheat to Rs. 100 or more in case of cotton on the average.

Supply of water on volume payment.

This question has exercised the minds of those interested in irrigation improvement for many years. The Irrigation Commission of 1901-03 drew particular attention to the matter and laid stress on the importance of evolving a reliable "module." In recent years a number of modules or semi-modules have been evolved, and of these the ones that have received most attention and success so far are Kennedy's Gauge-Outlet, Gibb's Module, and the Harvey and Stoddart's Standing-Wave-Outlet. The publications of the Irrigation Department may be referred to for full details of these. It may be noted here that Gibb's Module is designed to give a constant discharge with varying head within a certain maximum and minimum, and is partly independent of down-stream level. In the latter respect the three types are fairly satisfactory, and no increased supply can be obtained by silt-clearing in the watercourse as is the case with an ordinary outlet. Perhaps the most satisfactory in this respect is the Harvey type.

The Kennedy and Harvey types aim at giving a proportional discharge, and are thus semi-modules. The actual volume

passing through either can be ascertained by reading a calibrated gauge at the mouth. The Harvey type can be made into a constant supply outlet. A large scale test of the Gibb's Modules is being conducted on the Shahkot Distributary of the Lower Chenab Canal, and they are said to be working satisfactorily. A large number of Kennedy outlets have been installed on various canals, and are said to be giving satisfactory work as far as equable distribution is concerned. The Harvey type is being tested at Lyallpur, particularly by Mr. Lindley, in the Jhang Division, Lower Chenab Canal, and on a small scale at Khanewal and in Multan. Mr. Crump at Balloki has also recently made important improvements on the Harvey type of outlet. For all these some head is destroyed, *i.e.*, some command is lost. This varies from 5 inches to 8 inches for ordinary cases and with discharges of from 1 to 3 or 4 cusecs.

Value of volume pay cent to the zemindar.

If water was paid for by volume, the zemindar has every inducement to make the water go as far as possible, and to use it in any way he finds most profitable. It is true the charge for water is so low in comparison to the value of the crop that in general an effort is made to sow as large an area as possible. Supposing, however, that with a certain definite supply a zemindar ordinarily sows 11 acres wheat per square, from which he gets an average yield of 15 maunds. Now if he sows 12 acres, the average yield may go down to 14½ maunds, *i.e.*, his total yield is 174 maunds as compared to 165 on 11 acres. In other words he gets only 9 maunds on the extra acre, and yet on acreage rates he pays water-rate and land revenue on that at the same rate as the others. Hence beyond a certain point there is no strong inducement to economy by keeping to the present system, whereas if paying on a volumetric basis the charge would be the same in the two cases instanced above.

Another advantage would be that of getting rid of the Patwari and his exertions.

In order to encourage taking of water by volume, the rates charged per cusec per day should be such that the total charge is not more than ordinarily paid at present. The rates of Rs. 6 and Rs. 3 for rabi and kharif respectively on the Lower Bari Doab Canal were found to be much too high, and water is now being offered at Rs 5 and Rs. 2-8-0 respectively. It is very doubtful, however, whether many will take volumetric supply even at this rate, for there are still many difficulties involved. In the first place, when supplies are liberal a distributary often carries 10 per cent to 20 per cent. above designed

discharge, and the ordinary outlets benefit accordingly, whereas if water is taken by a module, the supply remains constant. Again remission rates ("kharaba") is given on a fairly liberal scale on canals if the crop is poor or a failure, but is not given in case of volumetric supply. These disadvantages, combined with the fact that the rate is comparatively high, especially for rabi, militates against the extension of this reform. If water is taken through Kennedy's Gauge-Outlet with an automatic recorder in the watercourse, the difficulty as regards flexibility and disputes regarding quantity given are largely eliminated. The ideal system would be the installation of meters such as those of the Kent Company. These are accurate within 1 or 2 per cent., but are expensive, and hence of limited application for zemindari outlets.

Silt in canal water.

The canals of the Punjab are made of earth, and owing to the velocity of the water carry fairly coarse silt. They are designed at such a slope that they silt slightly in the kharif when the rivers are in flood, and scour to some extent in the winter. They are therefore largely self-cleaning.

Losses by percolation.

Owing to percolation through the coarse silt at the bottom of canal beds and through the sides a considerable proportion of the water taken at the head of a canal is lost. The amount of this loss was estimated by Kennedy for the Upper Bari Doab Canal as 15 per cent, for main canal and 6 per cent. for minors and distributaries. More recent figures obtained on the Sirhind by Mr. Nicholson confirm this in general, and put the loss at 8 cusecs per million cubic feet of wetted perimeter. It has been estimated that in the Lower Chenab Canal these losses total 33 per cent. To save these losses experiments have been made to line canals with impermeable material like cement and bitumen.

* It was estimated by Mr. Curry in 1916 that lining could be done for Rs. 20 per hundred square feet. This means that a million square feet would cost 2 lakhs and might save 8 cusecs of water. Water-rate and land revenue total about Rs. 10 per acre, and taking a duty of Rs. 250 at distributary head, the value of a cusec to Government comes to Rs. 2,500, and of 8 cusecs Rs. 20,000, or a return of 10 per cent on the capital outlay. The cost of lining is, however, now much higher than Rs. 20 per 100 square feet, whereas canal charges and land revenue have remained constant. The value of the crops has, however, gone up even more than the cost of lining material, and the matter ought to be considered from a broader

* Punjab Engineering Congress, 1917.—"Lining of Canals by Mr. T. A. Curry."

basis than that of direct return based on existing water and land revenue rates.

On well land cultivators plaster their channels with clay to save losses. In case of "Tube Well" installation it would certainly appear to be very profitable to line channels.

Water-logging.

Another evil caused by percolation from the bed of the canals is that of raising of the water-table. In the Lower Chenab figures for a number of years show the rise of water-level is about $1\frac{1}{2}$ feet per annum. In some parts the water-table has already reached the surface and caused water-logging. The best example of this is to be seen at Hafizabad and on the Kot Nikka Distributary. The percentage of water-logged area on the Punjab canals is so far small—not more than 1 or 2 per cent., – but the serious aspect of the question is the fact that the rise of water-table is general throughout the Doabs, and there is no evidence so far of any slackening or reduction in this rate. There is no question whatever that when the water-table gets within 10 feet of the surface in any tract the future prosperity and productivity of that part is in a critical position, although serious damage to crops may not result until the water-table is within 4 or 5 feet of the surface. It must be emphasized that even a temporary rise of the water-table to within a few feet from the surface is harmful. A tract where the water-table is constant at, say, 3 feet from the surface can bear good crops, but another with a water-table 6 feet from the surface, but liable to a periodical rise to, say, 4 feet, will do very much worse. (See "kallar" below)

Drainage.

Drainage has been advocated as a cure for water-logging. Much confusion of thought exists on this question, and much useless expenditure has been incurred in consequence. Drains are certainly required for rapid removal of surface water due to rain or other causes. In connection with all canal systems, railways, roads, etc., the keeping clear of the surface drainage lines of a tract is of primary importance. As regards lowering of the water-table, however, this method both as regards initial cost and maintenance will in our opinion be found prohibitive and of very doubtful efficiency. Free water in the soil moves by gravity, and hence its natural direction is downwards. In a field with drains at a depth of, say, 3 feet, a water-table at 4 feet depth, no drainage would occur. If water is added on the surface, the water-table rises until it is at the height of the drains, when water will flow into the latter and drainage begins. If the drains are 40 feet apart, the water-table in

between the drains will be 1½ foot to 2 feet only from the surface, when the drains practically stop running. If the drains are in working order, crops will thrive under above conditions, provided the water-table does not remain long so near the surface. If the cause of the high water-table is percolation from the canal, it is likely to be permanent, and each irrigation given would cause temporary water-logging. In such cases it would probably be safe to give only "rauni" waterings even if a complete drainage system existed. "Kallar" would, however, probably give much trouble in such a case (see below). An ther difficulty with drains in the Punjab would be the necessity of large pumping installations to take away rapidly the water delivered by the main drains.

"Kallar" or salt from a high water-table.

As soon as the water-table reaches within 10 or 12 feet of the surface, the rise of water by surface-tension and its evaporation from the surface becomes considerable. This goes on constantly, and "kallar" thus tends to accumulate. As the water-table rises, the rate of increase of 'kallar" goes on more rapidly, and the land may go out of cultivation before actual water-logging occurs. This is the main danger in allowing the water to get too near the surface. Tracts where water-logging is already serious are distinguished by having a large band of "kallar" soil all round. Of course where rainfall is plentiful this feature is not prominent.

Causes of rise of water-table in dry canal tracts.

It is difficult to determine exactly the relative effect of percolation from the rivers, canals, and water-courses as compared to waste of water in the fields. A very brief discussion is possible only here. The question is being studied in detail by Mr. Wilsdon at Lyallpur. If, however, we take the case of the Lower Chenab Canal, and assume that of the total full supply of 10,700 cusecs, the amount percolating in main canals, minors and water-courses is *3,000* cusecs, then this amount flowing constantly to the subsoil in a doab of 5,000 squares would cover the ground to a depth of 8 inches or so. Assuming saturated soil contains 33 per cent. water, this 8 inches would saturate 24 inches of soil or raise the water-table by that amount. This factor alone therefore is sufficient to account for the present rise in the water-table. With rotational running of the canal in the winter, the amount is, of course, reduced somewhat, and at best the above is only a rough calculation. As far as the actual

Losses in the field.

field is concerned, a crop like wheat gets an average of between 10 and 12 inches of water. A considerable proportion of this, especially from the "*rauni*" and "kor" waterings, will evaporate from the soil

without passing through the plant at all. Assuming this is 25 per cent., or 3 inches, we have 7 to 9 inches left for actual transpiration through the plants. A large number of potculture and other tests made at Pusa and in America and elsewhere show that wheat requires from 350 to 700 pounds of water to pass through the leaves for each pound of dry matter produced. Taking 400 pounds as a conservative figure and a yield of 18 maunds grain and 36 maunds bhusa, we have a total yield of 54 maunds. Deducting 10 per cent. for moisture, we have roughly 49 maunds dry matter requiring 49 × 400 maunds of water transpired, or roughly 700 tons, equal to 7 inches of water per acre. It must be remembered that crops of wheat of 25 to 30 maunds grain are common, hence there does not seem to be much room for losses by percolation to the water-table. Work now in progress by Mr. Wilsdon, however, indicates that some at least of the water given at each irrigation does penetrate to subsoil. So far it has not been possible to give a direct quantitative estimate of this percolation.

From what has been said above it will be seen that lining of the canals would appear to be the final cure of water-logging, and that in addition the financial value of the water saved deserves careful consideration.

Intensity of cropping on canal land.

Most of the canals in the Punjab are designed for 66 per cent. intensity of cultivation. In the Lower Chenab the "haq" was raised from 66 per cent. to 75 per cent. The actual irrigation done is generally 100 per cent., and the zemindar is very dissatisfied if he cannot reach that figure, which after all only means one crop per annum only on the whole of this area. Even in the Lower Bari Doab Canal recently completed and designed for 66 per cent., the irrigation is approximately cent per cent. The fixing of a low "haq" not only protects Government against failure to fulfil expectations, but has in the past undoubtedly acted as an incentive to economy of water through the desire of the zemindar to grow at least one crop per acre per annum. This result has, however, not been obtained merely by economy, for supplies are liberal during the early years of a new canal, and the percentage of cultivation is approximately 100 from the start, though later this percentage is maintained on a smaller supply of water. Successful colonization would be a very difficult matter if the designed percentage of irrigation had been adhered to. Sindh offers a good illustration of this. In that province the so-called "fallow rules" lay it down that land should be cropped once in three years only. In the Jamrao canal, which is the only semi-perennial canal constructed so far, the actual

irrigation done is only about 45 per cent. The tendency there is to leave part of the holding permanently fallow and uncultivated, as it would take too much labour to keep it in a clean condition. Weeds flourish in consequence, and the standard of cultivation and of prosperity is very much lower than in any of the Punjab canals. An intensity of 50 per cent. is proposed for the new Sukkur Barrage Canal, which will make its chances better than that of the Jamrao. In Sindh cultivators prefer kharif or summer crops, but the tendency with low intensity will be to go in for more rabi cropping as in the Punjab colonies.

Maximum intensity of cropping.

In Egypt an intensity of over 200 per cent is generally attained, and that country has the highest record in the world as regards average yield of cotton. Examples of 66 per cent., 100 per cent., 133 per cent. and 166 per cent. intensity are the following, being tested now at the Lyallpur Farm :—

	Year	*Rabi.*	*Kharif.*	
I.	1920-21	Wheat	—	Wheat is over by April, and the land is fallow from April till following March, *i.e.*, 11 months. Cotton sown in 1922 is over by January 1923, and land fallow for wheat till November, *i.e.*, 9 months. **66 per cent. intensity.**
	1921-22	—	Cotton	
	1922-23	—	—	
	1923-24	Wheat	—	
II.	1920-21	Wheat	—	Five months fallow between wheat and gram; practically no fallow between gram and cotton, and nine months fallow after cotton before wheat is sown. **100 per cent. intensity.**
	1921-22	Gram	Cotton	
	1922-23	—	—	
	1923-24	Wheat	—	
III.	1920-21	Wheat	"Toria"	Four months fallow between wheat and "toria;" 3 months between "toria" and cotton; 5 months between cotton and "guara;" and 6 weeks between "guara" and wheat again. **133 per cent. intensity.**
	1921-22	—	Cotton	
	1922-23	—	"Guara" (green manure).	
	1923-24	Wheat	—	
V.	1920-21	Wheat	Fodder	Two months between wheat and fodder; one month between fodder and gram. Cotton follows gram immediately, and "senji" is sown in "vadh" of cotton Seven months fallow before wheat. **166 per cent. intensity.**
	1921-22	Gram	Cotton	
	1922-23	"Senji"	—	
	1923-24	Wheat	—	

All the above are three-year rotations. In No. IV it will be seen there are two fodder crops. Increasing the intensity of cropping would inevitably tend to increase fodder growing, and thus lead to more cattle being kept, and hence more manure being available.

Possibility of increase of intensity.

The canals for purposes of economy in construction are designed in the main to carry as much rabi supplies as are available. Development has proceeded beyond the limits when the canals can run full supply during rabi, but in some, *e.g.*, the Lower Jhelum, even now the kharif supply is only 10 per cent. greater than the rabi supply. Without arrangements for storage the limit has been practically reached as regards rabi supplies, except in the Indus. Even such supplies as may be available from the Woolar Lake Project and others would probably be best utilized in the huge tracts still undeveloped in the Western Punjab and Sindh. There remains the enormous kharif supplies in the rivers, not more than 20 per cent. of which are now utilized between April and September. These matters being somewhat controversial, those interested are referred to publications noted below.*

It may be noted that generally the proportion between rabi and kharif cropping varies between 2 : 1 and 3 : 2 on most of the western canals. In the Lower Bari Doab Canal a step in the right direction is being attempted in equalizing kharif and rabi cropping. If combined with a higher intensity, a new field of development will be opened out for the future of canal irrigation in the Province.

New canal projects.

The most important of these is the combined Sutlej Valley and Bhakra Dam Project with a maximum supply of 56,000 cusecs, or five times that of the Lower Chenab. An area of a million acres in the Nili Bar in Montgomery and Multan districts will get perennial irrigation from this scheme as well as large tracts in Bahawalpur State, all of which is suitable for American cotton and other valuable crops.

The Sind Sagar Doab taking from the Indus at Kalabagh is another big project designed to command two million acres. This and the Sutlej Valley Project are expected to be commenced at an early date. For fuller details of this and other minor projects, such as the "Haveli" and Woolar Lake Projects, see Indian Cotton Committee's Report, pages 24 and 25.

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*1. Punjab Engineering Congress Report, 1918. "The extension of American cotton cultivation under irrigation in the Western Punjab and Sind" by W. Roberts.

2. "Indian Cotton Committee Report," pages 19—23, 57, and 61.

CHAPTER VIII.—GROSS RETURNS FROM VARIOUS SYSTEMS OF FARMING.

The unit taken for a self-contained holding is the area which one plough can manage. This varies according to whether the cultivation is on canal, well or rain (*barani*) land. It also varies largely according to the intensity of the cropping. In the Lower Chenab Canal a plough manages from 10 to 14 acres, whereas in the Lower Bari Doab, at present, one plough often manages a square. On well land one pair is required for the well and one for cultivation ; the area per pair varying from 5 to 10 acres as a rule. The capital required in canal areas assuming a uniform area of 12 to 14 acres or half a square is estimated below—

Capital required for ½ square in Lyallpur (under one plough).

	Rs.	a.	p.
One pair bullocks	300	0	0
One yoke "panjali"	2	0	0
Two tying chains (ropes)	1	0	0
Desi plough	4	8	0
Two "jhuls"	4	0	0
"Taranti" (2) at annas 8	1	0	0
"Khurpas" (2) at annas 8	1	0	0
"Kasi" (2) at Re. 1/8	3	0	0
"Karah"	3	0	0
"Trangli"	1	8	0
"Sanga"	1	0	0
"Phalla"	0	8	0
"Chhaj" (2)	0	12	0
"Sohaga"	4	0	0
"Pahora"	0	6	0
"Kulhari"	0	12	0
"Jandra"	1	0	0
"Toka"	1	0	0
Baskets (2)	0	8	0
"Chhiklis" (2)	0	12	0
Total ...	331	10	0

In addition to the above the zemindar would generally have two or three young stock valued at Rs. 100 bringing the total capital to Rs. 430 irrespective of the cost of buildings. The latter are generally made locally and may be taken to cost about Rs. 200 per tenant. On new land where wood is available, the cost is much less.

The above estimate of capital applies to average conditions. Many zemindars possess cattle worth from Rs. 500 to Rs. 800 a pair, whereas others struggle along with inferior cattle often costing only Rs. 100 to Rs. 120 a pair. The young stock kept is generally bred by the zemindar.

If the zemindar is cultivating a square or more he will generally possess a cart and other extras not included above.

For well irrigation the following additional capital is required: —

	Rs.	a.	p.
Cost of well	750	0	0
Cost of Persian wheel	150	0	0
Extra pair of cattle	300	0	0
"Sohaga" (large)	7	0	0
Yoke (2)	4	0	0
Tying chains	1	0	0
Plough (1)	4	8	0
Total ...	1,216	8	0

Or a total of Rs. 1,650, roughly, apart from buildings. On "barani" land the capital required is similar to that on canal irrigated land; but one plough would manage in former case from 21 to 24 acres according to the intensity of cropping, which depends mainly on the rainfall.

Profits from 1 square on the Lower Chenab Canal.

The usual cropping is given in Chapter VI. The intensity at Lyallpur may vary from 80 per cent. to 120 per cent., the average being just over 100 per cent. The cropping in four cases of 80 per cent., 100 per cent., 120 per cent. and 160 per cent. will be considered below.

Case of 80 per cent. intensity of cropping.

This is the lowest intensity feasible for successful cultivation, though on the Lower Bari Doab a proportion of cultivators

are doing much less. One pair of working bullocks would be kept per square and three or at most four acres of fodder would be grown. Only ½ acre would be double cropped leaving 5½ acres fallow.

The cropping under the various intensities given above may be as follows :—

Crop.	80 per cent.	100 per cent.	120 per cent.	160 per cent.
Wheat	8	10	11	7
Gram	3	2	2	5
"Toria"	2 or 1	2½	3	1
Cotton	3 or 4	4	5	6
Maize	...	1	1	2
Sugarcane	...	1	2	3
"Chari guara"	2½	2½	2	4
"Guara" (green manure)	...	...	1	4
"Sag" (turnips)	1	1	1	1
"Senji"	½	1	2	4
Early fodder	...	...	...	3
Total cropped area ...	20 acres	25	30	40
Fallow ..	5½ acres	1	...	...
Area double cropped ...	½ acre	1 acre	5	15 acres.

The double cropping in case of 120 per cent. may be as follows :—

"Chari guara" mixture 2,	Gram 2 ...	... 2 acres.
Maize 1	"S.nji" 1 ...	... 1 acre.
Cotton 1	"Senji" 1 ...	... 1 ,,
"Guara" 1 ...	Wheat 1 ...	... 1 ,,
		5 acres

and in case of 160 per cent. as follows :—

"Chari guara" mixture 4,	Gram 4 ...	... 4 acres.
Early fodder 1 ...	Gram 1 ...	... 1 acre.
Early fodder 2 ...	Wheat 2 ...	... 2 acres.
Maize 2	"Senji" 2 ...	... 2 ,,
"Guara" 4 ...	Wheat 4 ...	... 4 ,,
Cotton 2	"Senji" 2 ...	... 2 ,,
		15 acres.

Many variations are possible such as increase of "toria" area at the expense of gram or wheat. It will be seen that in the above cropping there is 18 acres of rabi and 22 acres of kharif. Of the total cropping 16 acres consist of fodder crops of which at least 12 are mainly legumes.

The gross return in each case and expenses for land revenue, water-rate and cess only may be estimated as follows :—

80 per cent. intensity.	*Grain.*	*Fodder.*	*Expenses, Water-rate, Land Revenue, etc.*
	Rs.	Rs.	Rs. Rs.
8 acres wheat at 14 mds. at Rs. 4-3-0 and 21 mds. "bhusa" at annas 8	504	84	at 10=80
3 acres gram at 12 mds. at Rs. 4-4-0 and 12 mds "bhusa" at annas 4	153	9	at 10=30
1 acre "toria" at 7 mds. at Rs. 6	42	...	at 10=10
4 acres cotton at 6½ mds. at Rs. 12	312	...	at 10=40
2½ acres of "chari guara" at Rs. 64	...	160	at 8=20
1 acre "sag" at Rs. 64 ...	...	64	at 10=10
½ acre "senji" at Rs. 32 ...	...	32	at 10= 5
	1,011	349	195
Total ...	Rs. 1,360		

Gross return after deducting land revenue, etc.—Rs. 1,165.

This does not allow for interest on capital, renewals, cost of seed, and depreciation.

120 *per cent. intensity.*	*Grain.*	*Fodder.*	*Land Revenue, Water-rate, etc.*
	Rs.	Rs. a. p.	Rs. Rs.
11 acres wheat	693	115 8 0	at 10=110
2 acres gram	102	6 0 0	at 8= 16
3 acres "toria"	126	...	at 10= 30
5 acres cotton	390	...	at 10= 50
1 acre maize at 20 mds. at Rs. 3-8	70	—	at 10= 10
2 acres sugarcane at 25 mds. "gur" at Rs. 8 ...	400	...	at 15= 30
2 acres "chari guara" at Rs. 64 per acre	...	128 0 0	at 8= 16
1 acre "guara" at Rs. 64 per acre	...	64 0 0	at 8= 8
1 acre turnips at Rs. 64 ..	...	64 0 0	at 10= 10
2 acres "senji" at Rs. 64 ...	...	128 0 0	at 10= 20
	1,781	505 8 0	300
Total ...	Rs. 2,286-8-0		

Gross return after deducting land revenue, etc.—Rs. 1,986-8-0.

160 *per cent. intensity.*	*Grain.*	*Fodder.*	*Land Revenue Water rate, etc.*
	Rs.	Rs. a. p.	Rs. Rs.
7 acres wheat at 14 mds. at Rs. 4-8-0	441	73 8 0	at 10=70
5 acres gram at 12 mds. at Rs. 4-4	255	15 0 0	at 8=40
6 acres cotton at 6½ mds. at Rs. 12	468	...	at 10=60
2 acres maize at 20 mds. at Rs. 3-8	140	...	at 10=20
1 acre "toria" at 7 mds. at Rs. 6	42	...	at 10=10
3 acres sugarcane at 25 mds. "gur" at Rs. 8	600	...	at 15=45
4 acres "chari guara" at Rs. 64	...	256 0 0	at 8=32
4 acres "guara" at Rs 64 ...	...	256 0 0	at 10=40
1 acre turnips at Rs. 64 ...	...	64 0 0	at 10=10
4 acres "sag" at Rs. 64 ...	...	256 0 0	at 10=40
3 acres early fodder at Rs. 48	...	144 0 0	at 8=24
	1,946	1,064 8 0	391
Total ...	Rs. 3,010-8-0.		

Gross return after deducting land revenue, etc.—Rs. 2,619-8-0.

The estimates and cropping given above are tentative and intended to show how the gross returns depend mainly on the amount of water or the intensity of cropping. No attempt is made to work out nett profits, but it may be noted that a tenant doing 80 per cent. would probably have two working cattle and three young stock. His standard of cultivation would be low as the area of crop for one plough is excessive but would scarcely suffice for two pairs. In the case of the 160 per cent. intensity there would be three pairs of working cattle and probably 12 young stock if not more. Very much more manure would be available per square and the standard of cultivation would in consequence be high. The labour force on land in the Lyallpur colony is generally estimated at two men per plough. Land doing 100 per cent. cropping rents at Rs. 300 to Rs. 500 per square.

Case of well land.

The profits under well cultivation owing to the high cost of raising the water are generally much less than on canal land under similar conditions. Of course, land near a town, where facilities for purchase of manure and for sale of perishable produce in the form of vegetables and fodder are ample, will give very large returns.

"Barani" land.

The gross returns are in this case liable to great variations and no general figures can be given.

CHAPTER IX.—WEEDS.

1. A plant out of its proper place may be technically called a weed. From a farmer's standpoint only that plant is a weed which is injurious to crops, or is troublesome and unsightly.

Annual losses due to the occurrence of pernicious weeds upon farm lands, though acknowledged in a general way, are far greater than are realised. The figures would be alarming if these losses be interpreted in terms of money for the whole country. Weeds not only reduce the yield of crops by robbing plant food and moisture but certain weeds get such a hold on some soils that cultivation becomes impossible on them. These losses can be considerably lessened by treatment based on an accurate knowledge of the nature of each weed.

Losses due to weeds.

1. Weeds rob the soil of plant food and moisture.

2. They are hardier than many of the garden and field crops and therefore crowd out the useful plants.

3. Work in their eradication increases the cost of cultivation.

4. Weeds harbour insect and fungus pests.

Classification of weeds.

(*a*) According to the length of time they live, weeds are classified into—

1. Annual weeds which live for one year only, as "poli," "piazi" and "bathu".
2. Biennial weeds which live for two years.
3. Perennial weeds which live for more than two years, as "dub," "baru" and "dabh" grasses.

(*b*) According to the season in which they grow, the weeds are known as kharif weeds or rabi weeds—

1. Kharif weeds are those that grow from April to September, as "motha," "baru" grass and "kutta" grass.
2. Rabi weeds are those growing period of which extend from September to April, as "piazi," "bathu" and "poli."

General principles of eradication of weeds.

In eradication of weeds it is important to know to which class a certain weed belongs, for in case of annual and biennial weeds the treatment is usually to prevent them from seeding, while in case of the perennial weeds the formation of new leaves and roots and underground stems is to be stopped. It is essential to know the habit of growth as well as time of germination and ripening. Specific treatment for eradication of important weeds will be given along with their description. The general principles are, however, given below :—

(1) Never allow weeds to ripen seeds, for we know "One year's seeding, seven years' weeding."

(2) All weeds bearing mature seeds should be burnt or thrown in places from which they cannot be carried easily to fields by wind, water or animals. Sometimes such weeds are fed to cattle and the refuse is taken to the manure heaps, from where they find their way to the fields. A manure containing such weed seeds should never be applied fresh.

(3) Be always on the alert to prevent new weeds from becoming established.

(4) Use always clean seed.

(5) Efforts for eradication of perennial weeds should be persistently made. Imperfect treatment such as a single ploughing may do harm instead of good by breaking underground stems and stimulating their growth.

Kharif weeds.

1. "Dub" or "Khabbal," "talla" (*Cynodon dactylon*)—Perennial.

Natural Order—Gramineæ.

"Dub" grass is found in all soils excepting very light ones. In rich soils, however, its growth is very luxuriant. Its presence generally indicates that a soil on which it is growing is a good soil. This grass is considered to be the best fodder grass for all classes of domestic animals, and especially for horses. When made, into hay it keeps well and is a good fodder. It is a perennial grass, but growth ceases in severe winter months.

Method of eradication.—Land badly infested with this grass should be put under wheat for a year or more. Cultivation required for wheat will destroy "dub" grass. Iron ploughs

are more effective for this purpose than "desi" plough. They should not be worked deeper than 4 inches, so that the roots may be exposed and not buried in the soil. If possible uprooted grass should be taken out of the soil by hand or by use of harrows.

2. "Baru" grass (*Sorghum halepense*)—Perennial.

Natural Order—Gramineæ.

It is a tall perennial grass with creeping *Rhizomes* which throw up many shoots. Its growth is checked in winter. It is found on both light and heavy, and on cultivated and uncultivated, soils. It is used as a fodder for cattle, but is said to be poisonous when quite young, or, if subjected to drought, on account of the presence of hydrocyanic acid. No such injurious effects are, however, reported from Australia or United States of America, where it is also used as a fodder.

Eradication.—On account of its vigorous underground stems (*Rhizomes*) it is a very hard weed to eradicate. A single ploughing will stimulate its growth by breaking underground stems, and thus increasing the number of plants. Persistent efforts should be made to combat this pernicious weed. Iron ploughs should be worked as deep as possible. The spade will have to be used in some cases. All the underground stems brought up by cultivation should be collected and burnt when dry, otherwise some of them are likely to strike roots again. Its above ground stems should not be allowed to mature seed even if the destruction of underground parts cannot be taken up at once. This will check its further spreading.

Eradication of "baru" should be taken up at its first appearance. It requires a lot of labour and time to eradicate if "baru" is allowed to establish itself on the land. Efforts at eradication must be continued persistently until the land is quite clean.

3. "Dabh" or "kussa" grass (*Eragrostis cynosuroides*)—Perennial.

Natural Order—Gramineæ.

It is a perennial grass with thick *Rhizomes*. It is abundant in all kinds of soils, and especially in low lying "usar" lands, or "bet" and "hithar" lands near the rivers. It is not liked by cattle except when it is very young. In time of famine, however, it gives some relief as a fodder, as it is a very hardy grass and resists drought more than many other ordinary grasses.

Sometimes it occupies the land to such an extent that the "desi" plough cannot enter it, and no cultivation is possible on such land. Examples of such lands are to be found in the

"hithar" tracts of Chunian and Qasur and in the Ferozepore District. "Kussa" grass is held sacred by the Hindus.

Eradication.—The best method of cleaning lands infested with "dabh" is to plough them with inverting ploughs as deep as possible and to take out the underground stems thus brought up. This treatment should be continued until the land is quite clean of this weed.

Another perennial grass with extensive creeping roots is also known as "dabh" or "kussa" grass. (*Imperata arundinacea*). It is widely dispersed in hills and plains, especially in clayey soils where free water is near the surface. Methods of eradication are similar to those in case of *Eragrostis cynosuroides.*

4. "Dila" or "motha" (*Cypperus tuberosus*).

Natural Order—Cyperaceæ.

"Dila," though a perennial plant, grows only in summer. It is generally found in sugarcane fields which are watered in the hot months. It has got underground black tubers from which shoots come up the following year It also propagates from seed. It is a very quick growing plant, and sprouts even one day after it is cut with a "khurpa." It is considered to be a poor fodder, but its value is appreciated in May and June, when no other grass grows, and people frequently bring it from cane fields which are watered in those months. It is chopped and mixed with "bhusa." After the rains begin and other grasses come up "dila" gets out of favour.

Eradication.—Sugarcane fields should not be followed by a kharif crop next year on lands where "dila" is very troublesome. Sugarcane should be followed (as is generally done) by wheat, for' which land should receive cultivation in May and June, so that the tubers of "dila" may be killed. This weed is not yet so serious in the colonies as in the cane growing submontane districts.

5. Many annual grasses, such as (*i*) wild "sanwank (*Panicum colonum*), (*ii*) "madhana" (*Eleusine egyptiacum*), (*iii*) "phulan," (*iv*) "lanb" grass (*Eragrostis sp.*), (*v*) "bunin" and (*vi*) "bhurat" (*Cenchrus catharticus*) or (*Cenchrus echinatus*), etc., etc., grow among the crops and bare lands in rains. Some of these grasses, as No. (*i*) and No. (*ii*), are believed to be good fodder

grasses, while others have little nutritive value. All these grasses can be eradicated from crops by interculture and from fallow fields by cultivation. Once they are uprooted most of them do not sprout again. They should not, however, be allowed to mature seeds. The grain of wild "sanwank" (*Panicum colonum*) is eaten by the Hindus on fast days.

6. "Itsit" (*Boerhaavia diffusa*) and (*Trianthima pentandra*).—These two plants are known as "itsit" in Punjabi. "Itsit" is a common weed in the rains, especially in the manured land and on waste lands where dung cakes are made. It is browsed on by animals.

7. "Tandla" (*Digera arvensis*) is a common kharif weed in the Punjab plains. It is used as a pot-herb by the poor, and is also used as a fodder. It is an annual plant, and is not hard to eradicate.

Rabi weeds.

1. "Piazi" or "bhughat" (*Asphodelus fistulosus*)—Annual.

Natural Order—Liliaceæ.

A very common weed in the rabi season, but ordinarily of no use as a fodder or a pot-herb. Seed germinates in October and November, and flowers are formed in March Seed ripens along with wheat.

Eradication.—In canal irrigated tracts, fields watered and prepared for wheat should be left for about a week. "Piazi" seeds will during this time germinate. The young seedlings will be destroyed when the fields are ploughed for sowing wheat. This process is called, "dáb". "Dáb" is not possible for very late sowings. The Bar harrow if used on young wheat also eradicates to some extent the young seedlings of "piazi." In all other cases plants should be cut below the crown of leaves before the seed is ripe. Use always seed free from "piazi" seed.

(2) "Bathu" (*Chenopodium album*)—Annual.

Natural Order—Salsolaceæ.

"Bathu" is one of the most troublsome weeds in wheat and winter garden crops. It is used as a pot-herb by the poor and also as a fodder. Seed of "bathu" ripens earlier than wheat.

Eradication.—It ripens its seed much earlier than is generally realised. The whole plants and spikes are quite green when seed

is quite ripe. If the plants are fed to cattle at this stage, some seed is sure to find its way to the fields through the manure. Such plants should not be fed to cattle, and, if done, the refuse should not be taken to the manure heap, especially if it is soon to be carted to the fields. Such plants should not also be allowed to remain in the field after being cut. "Bathu" plants sprout again if cut above ground. They should therefore always be cut with the "khurpa" a little below the surface of the ground.

"Bathu" seed germinates slowly. Therefore "dáb" is not so useful for it as for "piazi" (*Asphodelus fistulosus*). Very young "bathu" plants can be eradicated to some extent if a Bar harrow or a peg tooth harrow is worked in the field.

Seeds of all the rabi field crops (wheat, oats, gram, barley, etc.) should be passed through a winnower should they contain weed seeds. Seeds of many weeds such as "bathu," "piazi," "lehli" (*bind weed*) and "dokan" (*Lathyrus aphaca*), etc., etc., will mostly be removed in this way.

(3) "Poli" (*Carthamus oxyacantha*)—Annual.

Natural Order—Compositæ.

The plant has no spines when young. It is used as a fodder, and sometimes as a pot-herb by the poor, at this stage. The seed is roasted and eaten by poor people. The seed is ripe in May. An edible oil is also extracted from the seeds, which is said to be used for adulterating "ghee."

Eradication.—It is a very bad weed if once established. Some lands in the Ferozepore District are so much infested with it that rabi crops cannot be harvested if sown there. Early action should be taken if this weed seems to be increasing year by year. Seed ripens in May. All the plants should therefore be cut down immediately after harvesting wheat if not taken out while young. A reaper can be used with advantage for this purpose. All people affected should take up this business, otherwise seed will be blown from neighbouring fields to those from which plants have been removed.

(4) "Leh" (*Cirsium arvense*)—Annual.

Natural Order—Compositæ.

It is commonly found in "bet" lands and also in some other places. It is of no use to man as well as to cattle. Seeds have

got hairy appendages by which they can be easily blown away by wind. Plants should be cut or ploughed up with an iron plough before the seed is ripe. The "desi" plough is not useful for this purpose, as the roots of this plant are very deep and cannot be broken with it.

5. "Lehli," "bakar bel" or "verhi" (*Convolvulus arvensis*) —Perennial.

Natural Order—Convolvulaceæ.

"Lehli" is a common weed in the Punjab. It is perennial and deep rooting with extensive creeping cord-like fleshy root stocks These root-stocks throw up slender stems, which twist around the stems of crops, using them as supports, and partly choking them. It grows throughout the year, though growth is much more active in winter. "Lehli" weed is a good fodder for cattle, sheep and goats.

Its propagation is both by seed and running root-stocks, every portion of which will give rise to a new plant if broken by the plough in moist soil. Though growing throughout the year, its seed ripens in April and May.

It is exceedingly hard to eradicate owing to the vitality of the fleshy root-stocks. Care should be taken that seeds of winter crops do not contain "lehli" seed. The plants of "lehli" should be cut with "khurpa" or "dranti" persistently during its growth. In fallow fields the persistent use of "panjdanta" with broad "khurpa" like scrapers has proved very useful to eradicate "lehli." Second crop of this weed should not be allowed to manufacture sufficient food to nourish the underground root stocks after the first one has been destroyed.

6. "Maina" (*Medicago denticulata*)—Annual.

Natural Order—Leguminosæ.

"Maina" is an annual weed growing in winter. It is a leguminous plant, and is used as a fodder for cattle. It is said to cause colic in horses. Sometimes its seed is sown in "toria" and cotton fields in October. After the main crop is removed "maina" is irrigated. "Maina" should be fed before its stems, which are wiry, become too hard and the pods are ripe.

Poor people use it as a pot-herb. "Maina" becomes a serious weed in the submontane tracts only in those years when it rains too much in winter. "Maina" is found generally on heavy and loam soils. It is not a common weed on light lands.

Eradication.—Cut it and use it as a fodder before its seed is ripe. Being a leguminous plant it enriches the soil if ploughed in with an iron plough on fallow lands. Winter crop seeds should not contain "maina" seed.

7. "Maini" (*Trigonella polyserrata*)—Annual.

Natural Order—Leguminosæ.

"Maini" has a darker colour than "maina". Its leaves are dented and pods are straight. It is used as a pot-herb and also as a fodder. "Maini" grows on light lands where "maina" is not so common It is said to cause sometimes tympanitis when fed to cattle. Methods of eradication are similar to those in case of "maina".

8. "Takla" or cow cockle (*Saponaria Vaccaria*)—Annual

Natural Order—Caryophyllaceæ.

It is an annual weed with pink flowers frequently met with in wheat fields. Its seed is round and dull black in colour about $\frac{1}{12}$th inch in diameter. It not only robs the plant food and moisture, but its seed forms an objectionable impurity in commercial wheat.

Eradication.—Use pure seed and pull out all the plants of "takla" before its seed is ripe.

9. "Rari" or "rewari" (*Vicia sativa*)—Annual.

Natural Order—Leguminosæ.

It is an annual leguminous winter weed and is used as a fodder.

Eradication.—Use pure seed and cut the weed plants before its seed is ripe and use as fodder.

Many other annual weeds are met with in winter such as "shahtara" (*Fumaria parviflora*), "kurund" (*Chenopodium murale*), "dhabbar" or "chandni' (*Anagallis arvensis*), "farid buti" (*Farsetia Edgeworthii*), etc., etc. Generally they are not so troublesome as those mentioned above. To keep them in check never allow them to ripen seeds.

PART II—CROPS.

CHAPTER X.—WHEAT, BARLEY, AND RICE.

WHEAT.

Natural Order—Gramineæ, tribe Hordeæ.

Botanical name—*Triticum sativum.*

Vernacular name—*Kanak.*

Area.

Wheat occupies a much larger area in the Punjab than any other crop; it is the staple food of most Punjabis, and is also the chief crop for sale and export in most districts. The area is generally over nine million acres, of which half is irrigated and half unirrigated or "barani." The area under irrigation is very constant from year to year, whereas the "barani" area, depending as it does on rainfall, is liable to considerable variation, thus bringing the total area sometimes to nearly ten, and at others to only just over eight million acres. The actual area for the qiunquennium ending 1917-18 was 9,354,524 acres. As the total area under all crops is generally about 28 million acres, varying by two or three million on either side, it will be seen that wheat constitutes from 30 to 35 per cent. of the area of crops. It may be of interest to note also that 40 per cent. of the total wheat area of India is found in the Punjab. As regards tota production, India comes after Russia and the U. S. A., the next in importance being Canada.

Yield.

The outturn on unirrigated land may be taken to vary from ·25 to ·3 tons (9¼ to 10½ bushels) per acre, and on irrigated land at ·45 to ·5 tons (16 to 18 bushels) or 12 to 13¼ maunds, so that the total yield in fairly good years is between 3 and 3½ million tons corresponding to 110 to 120 million bushels. The yield of wheat in other countries for comparison with the acre yields in the Punjab is given in Chapter I.

Classification.

A wheat field in the Punjab generally consists of a number of different types of plants with one predominating. Over forty such types have so far been isolated. They all belong to one or other of the three sub-races: *T. durum* ("wadanak" or macaroni wheats), *T. compactum* (dwarf wheats), and the ordinary *T. vulgare.*

"Wadanak" wheats.

There are three varieties isolated so far. All have bearded ears, tall strong straw, and peculiarly long grain, which is very hard. These wheats are generally only grown on well land highly manured, and may be seen under such conditions all over the Province. Under such circumstances they will yield heavily, and will be much less inclined to lodge than any other variety. Moreover the grain usually commands a premium of a few annas per maund in the market; this is due to the fact that the flour, though of little use for making bread or "chappatties," is used in the manufacture of the sweetmeats which are eaten by all classes. The area of these varieties is strictly limited by the fact that they only yield well when receiving heavy watering and on rich or manured land.

Compactum wheats.

There are only four or five types of the compactum or dwarf wheats, and they only form an important part of the mixture of types on a small area in the south-west of the Province. One variety only has bearded ears. The heads are short and very dense, and the straw is short and stiff; the grain is much shorter and more rounded than that of ordinary wheat. These wheats yield fairly well, and especially they are said to ripen well in spite of early hot weather. They yield good flour, but the grain is not favoured in the export market owing to the necessity of specially adjusting the cleaning machinery to deal with a small quantity of wheat of such peculiar shape.

T. Vulgare.

The bulk of the wheat of the Province consists of the ordinary variety, *T. vulgare.* There are a large number of types of this growing here which differ practically in every possible way. Three kinds are most common. On the unirrigated land and many well lands the common wheats have red grain and bearded ears classified according to Howard's classification as types 13, 14 and 15; the former with red chaff, and the latter two with white chaff.

In the canal colonies the commonest wheat, and the one grown for sale in the export market, is No. 11, known as "Lal kasarwali." This is bearded and has smooth chaff. The flour which it yields is not particularly good, but is of about the ordinary quality exported from India. A beardless wheat, type No. 17, is grown on considerable areas in many parts of the Province, especially in these colonies, and is the commonest wheat in one or two parts. It does not yield so heavily as type 11, but it gives very good flour, and thus commands a small premium (two to four annas per maund) over No. 11 in the market. There are large number of other varieties which generally occur only

as mixtures in crops consisting mainly of one of the kinds already mentioned.

Soil.

Wheat is grown all over the Province and on all classes of land except the very lightest unirrigated high land. The heaviest type of soil is not well suited to wheat growing in this dry climate; but such very heavy land is very rare here. The districts producing the greatest quantities are those watered by the "Lower" (western) perennial canals, for the conditions of the water-supply there favour the growing of a very high proportion of wheat. In fact on most of the perennially irrigated areas wheat occupies between 40 and 50 per cent. of the total area cropped in the year. The well lands in the central districts are credited with the heaviest yields per acre; this is due more to the fact that wells are sunk on selected soil, which is also manured and very carefully cultivated, than to the difference in the nature of the water-supply.

Season.

Wheat sowing in this Province starts in the middle of October, and may continue into December, or even to early January in some parts, though crops sown in December and January will not give a maximum yield. The time of harvesting is remarkably regular year after year. In most places in the plains it always starts between the 15th and 20th of April, and very little, if any, remains uncut at the end of that month. In the south-east Punjab harvesting starts a fortnight earlier.

Fallows and rotations.

It has already been explained that wheat is practically always sown on land that has been fallow for several months; and it may also be said that most of the land which has been fallow during the summer months will be sown with wheat in the winter. On irrigated land the "long period" crops, cotton and sugarcane, are generally followed by wheat; it also follows fodders grown in the early part of the summer; and in most districts there are areas on which winter crops, mostly wheat, are sown for at least several years in succession. Maize is sometimes followed by wheat in eastern Punjab; but although the maize is manured, it is recognized that such wheat is at a considerable disadvantage. On unirrigated land wheat either follows a previous winter crop, or a summer crop of the previous year.

Mixtures.

Apart from the fact that a certain amount of an early winter fodder crop is often sown very thinly in the wheat fields, the bulk of the wheat is grown without any deliberate admixture of any other crop.

Occasionally it is mixed with gram. Both these practices have already been discussed in detail (*vide* Chapter II.) In all parts of the Province the crop is contaminated by a small percentage of barley, the presence of which lowers slightly the value of the whole, at all events for the export market. In Ferozepore District this mixture may be as much as 20 or 30 per cent., whereas in the colonies it is generally under 2 per cent.

Preliminary cultivation.

All over the Province it is considered, and rightly so, that the yield of a wheat field depends primarily on the excellence of the preliminary cultivation apart, of course, from the inherent ability of the soil and the water supply to nourish a crop. Indeed, even on any soil except coarse sand, if the preliminary cultivation is very good, good crops of wheat are grown with remarkably little water, though naturally, if it is very deficient the latter must remain the limiting factor. On unirrigated land, where only the country plough is used, twenty ploughings are said to be given sometimes: certainly ten is common in such circumstances. Even irrigated land is commonly ploughed five or six times, and the clods broken by several runs of the "sohaga." Wheat on any kind of land may be manured if manure is available after supplying the needs of the crops for which it is necessary; but manure is not regarded as being a prime factor in the production of a good crop of wheat. Only a small proportion of the crop is grown on recently manured soil.

Seed-rate.

The usual seed-rate is 24 seers. In some parts, *e.g.*, Karnal, it is as high as 40 seers, and, on the other hand, in some colony land as little as 16 seers is sometimes sown. Late sown wheat requires a higher seed-rate.

It may be of interest to note that a head of wheat generally contains 19 to 21 spikelets, each having generally 3, and sometimes 4 or 5 grains. Each grain which germinates and persists gives rise to an average of say 4 shoots, hence the number of grains from one seed may be 240. If every seed sown was successful, a seed-rate of 20 seers ought to give 120 maunds.

Harrowing.

The methods of sowing have already been fully described (see Chap. IV). One of the weakest points of the system on irrigated land is that the sown land is left smooth and pressed after the "sohaga" has been used to cover the seed. After this last pressing with the "sohaga" the land should be lightly harrowed, for which purpose the cheap Bar harrow introduced by the Agricultural Depart-

ment is quite suitable. The object of this is both to prevent evaporation during the first few days after sowing, when otherwise it is undoubtedly very rapid, and also to leave the surface in such state that the further harrowings may be more effective. The extent to which water may evaporate from the soil when it is thoroughly moist and left with a smooth pressed surface seems to be imperfectly realised by farmers in this country. Experiments in all parts of the world have shown that under such circumstances evaporation from the soil may proceed much more rapidly than from a free water surface. The conditions after the sowing of the earlier wheat fields are ideal for rapid evaporation.

After cultivation.

Very little is done in the ordinary practice to cultivate the soil after the crop has been sown. On irrigated land and on unirrigated land when rain falls early benefit should result from harrowing with a light harrow. It must be admitted, however, that experimental confirmation of this is still lacking. But observations on the Government farms and the opinions of farmers who have tried it support the view that harrowing during the early stages of the growth of the crop is beneficial, and there is no doubt that it does much good in removing such weed seedlings as those of "piazi" (wild onion), "rewari" and "bathu." It also seems that it is possible further to delay the first watering to a crop which is harrowed. But the after cultivation of the wheat fields is a matter which needs further investigation. For, as has already been stated, conclusive results of experiments in India definitely proving that a distinct increase in yield has been caused by this treatment have not been published, still less the results of any experiments which will show the exact details of the best way of doing it, the best depth to which to harrow, the best interval between successive harrowings, or the best stage at which to discontinue it. None the less the harrowing of young wheat is widely recommended. As stated above, it does not seem to diminish the crop, and is beneficial in keeping down weeds, and possibly in delaying the time when the first irrigation becomes necessary. It also checks white ants which tend to damage early sown crops.

Irrigation.

A large number of experiments carried out in this country and elsewhere indicate that under the very best conditions of soil and cultivation a maximum crop, which in this Province is about 40 maunds (53 bushels), can be grown on about 12 inches of irrigation water on a field scale, including the "rauni" irrigation, before sowing. Thus there will be less than this, say 10 or 11 inches of water, actually

eaving the soil by transpiration through the plants or evaporation from the soil during the growth of the crop.

To achieve such a high "duty" the losses by evaporation from the soil must be reduced to a minimum, and also the other factors, such as quantity of available plant food and the cultivation and condition of the soil, must be favourable. A large number of experiments carried out in America and at Pusa in India by Leather indicate that less water is required to produce a pound of dry matter in manured or well prepared soil than in unmanured or unprepared soil. This corresponds with general experience in the canal colonies, where the same amount of water, or more, on poor soils gives much less return than on good or manured soils. Again, the way in which the water is given affects the question. If given in small quantities, as in light showers of rain, or perhaps in such quantities as are given in well-irrigation, the losses by evaporation from the soil surface tend to be excessive. These can, of course, be minimised by harrowing. It should be noted also that in comparing the above to Canal "duties," the fact that in the latter water is measured at the head of the distributaries and not at the field should be borne in mind. The losses between the head of distributary and the field are often very considerable (see Chap. VII).

The ordinary practice in the canal colonies agrees fairly well with these figures. The ordinary amounts of irrigation may be expressed roughly as follows: an irrigation (called the "wahn") of about 4 inches depth for the preparation of the soil some months before sowing (omitted if there are timely rains). This must be neglected in making a comparison with the above statement, for in a dry year most of it will be lost by evaporation before sowing. A watering (the "rauni") before sowing, also probably more frequently about four inches, and two or three waterings after sowing, which will generally average three inches each or possibly slightly less, making a total of 10 or 12 inches altogether.

At Lyallpur heavy crops, *i. e.*, crops of 25 to 30 maunds of grain according to the season, have repeatedly been grown with only two waterings after sowing, making a total quantity, including rainfall, of ten or twelve inches. And it is known by farmers that first rate crops can be grown with only two waterings after sowing, provided that everything else, soil, cultivation, weather, freedom from attacks of white-ants and rust, and, above all, the times of the waterings, are as favourable as possible.

On most soils if a crop is to be grown with only two waterings, these must ordinarily be given about February 7th—10th and

March 10th —14th. A little variation may be necessary owing to differences in the seasons, and some latitude is possible on good soils. But the temperature here rises so rapidly in the spring, and growth is then so rapid that a delay of a week, when the crop is needing irrigation, may affect the yield. Thus, to grow a maximum wheat crop on two irrigations means that it must go without any watering for over three months after sowing. This cannot be possible unless the soil is fairly good and is free from "kallar" and white ants, and is not possible for early sown wheat, which must be watered in early December. Again, the canal runs with rotational closures, and only some fields can be irrigated exactly at the time the farmer would choose.

Hence it is that four waterings, including the one before sowing, *i.e.*, a total of about twelve inches, is regarded as the minimum number which are ordinarily needed for a maximum crop on most of the light unmanured soils which are commonest in the canal colonies. And there is no doubt that this is correct. It may be pointed out that this is almost as high a duty for the water as that obtained in the most careful American experiments with plants in pots or field crops, and higher than is obtained in general practice anywhere else in the world.

Necessity for further investigation.

It is remarkable that, so far as is possible, the same number and weight of irrigations are given to all soils, rich and poor, except that if there is surplus water after providing for the necessities of the other fields, it is used for the poorer lands. And also crops on land affected by "kallar" are more heavily or frequently watered, and a crop which is being attacked by white ants has to be watered simply to save it from destruction. But there is no definite principle which is followed in regard to the amount of water given to the crop according to the nature of soils. It is possible that the present practice is not far wrong, and that roughly it is best to give much the same amount to rich land as to poor; certainly it is impossible to suggest any improvement until the matter has been thoroughly investigated by field experiments. This would appear to be one of the most important fields for investigations in connection with irrigation farming in this Province

Pests.

The wheat crop suffers widely from two serious pests, and there are a number of others which cause some local damage. Whenever the soil in which the young wheat plant is growing dries beyond a certain point, and especially so in case of early sown wheat, and where the soil is not in very good condition, the roots are attacked by white ants. The crop is killed in small patches all over the field, and the damage

White ants.

is serious in light soils. Harrowing does some good, but the only certain cure is watering, when the trouble immediately ceases. After the first watering "kor," plants are rarely killed, though some damage may be done if the soil gets very dry. Attack by white ants, and not scarcity of water in the soil, very often determines the date of "kor" watering. All Punjab wheats are affected to some extent by rusts (*Puccinia graminis*), or black rust (*Puccinia glumarum*), or yellow rust (*Puccinia triticina*) or orange rust every year. Of these the yellow rust is most common. There is a considerable difference in liability between the various local varieties, whilst imported varieties are sometimes affected to such an extent as to give no return at all beyond a few very small shrivelled grains. There is not only variation from year to year in the degree of "rusting", but there is also great variation in the date at which it becomes widespread. In some years the attack is bad by the end of December ; in other seasons much rust is not seen until February. It is probable that the differences in the yield of wheat in different years on irrigated land are connected at least in part with the date at which the rust attack assumes serious proportions. For instance, at Lyallpur there is a maximum variation in the yield of the same variety of wheat in the best and the worst years, which must be estimated as at least 15 per cent., if not 20 per cent. And this appears to affect all classes of crop, including the maximum obtainable. There is remarkably little variation in the weather in the cold season in this part of the Province. The rainfall is at most only 3 or 4 inches and cannot have much effect when the irrigation is modified accordingly. Apart from this, the only important variations take the form of occasional spells of cloudy and cooler weather, which could not have a great direct effect on the yield. But these spells do seem to result in the sudden appearance or spreading of rust which would account for the depression of the outturn. This view receives some confirmation from the fact that the crop in a poor year contains a higher proportion of small or shrivelled grain. An early bad attack of rust seems to have a much more serious effect than one in late February or March ; during the latter month rust will badly damage only the late sown crops. The only measure possible against rust is to find a variety of wheat immune against it, and otherwise satisfactory. This has not been done here yet.

Rust.

Frost in the Punjab is seldom severe enough to have any great effect on wheat. Occasionally a late frost will do a little damage.

Frost.

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It is commonly said by farmers that hot winds at the en of March and early in April cause shrivel ing of the grain. This is a statement whic it is difficult either to confirm or contradict ; it can only be sai that experience at Lyallpur does not seem to indicate that th is a factor of great importance.

Hot winds.

Storms, usually on a quite limited area, do some damage t the crop practically every year during March and April. Ha is the worst feature of such storms, for it may be so heav as to destroy crops almost completely. Fortunately hail-storm seldom cover a very wide area, and are generally limited t strips of country only two or three miles broad. Some damag always occurs from the lodging of fields when any strong win arises, or rain falls late in the season shortly after they hav been irrigated. Such fields are further damaged by rats, whicl also are especially a nuisance on fields adjoining high waste land The wheats with strong grain are also very liable to attacl by rats.

It is also possible that rain in the latter half of February and in early March depresses the yield by preventing the proper fertilization of the wheat flowers, for it certainly happens that ir such cases many spikelets have only 2 instead of 3 or more grains, and the lower spikelets are often empty.

Whilst there are thus a number of ways in which the wheat crop may suffer from unfavourable weather, it must be noted that the total loss so caused never attains very serious proportions. As has been said, the annual variation in the yield of wheat on irrigated lands is generally only about 20 per cent. as a maximum ; and on unirrigated land the yield depends chiefly on the rainfall during the monsoon and winter and on the cultivation.

The harvesting of wheat begins about the middle of April and has to be finished as quickly as possible, for in this hot dry weather the wheat ripens very suddenly, and any delay means very serious loss from the shedding out of the grain. Some beardless varieties allow the grain to shed very readily, a factor which militates seriously against their general adoption on any but very small holdings. It may be also mentioned that birds attack beardless wheats in preference to bearded. There is usually a considerable incursion of special casual labour into the chief wheat growing tracts at this time of the year, and all available local labour is fully employed. The whole crop is out, tied up, and stacked in low stacks remark-

ably quickly. The corn is cut by hand very low by means of a very small saw-toothed sickle ("daranti.") After cutting it is tied into very large bundles, each as much as a man car carry. These are carried by hand to a central heap, where they are stacked to a height of six or seven feet to await the threshing. The grain is generally dead ripe when cut, and can be threshed at once. Five men will cut and stack an acre of crop in a day. They are commonly paid in kind, their share of the produce being worth about five rupees.

In the canal colonies the practice of using reaping machines is becoming more popular, though it has been hindered by the very high prices and difficulty in getting machines during the war. Where the holdings are big enough to allow of their use, the crop can be reaped much cheaper and more quickly by using the machine. At least two good pairs of bullocks and eight men must be employed if a full day's work is to be done.

The draft of the reaper is heavy, about 240 lbs., and the pace must be greater than the ordinary pace when ploughing. Thus repeated changing of the bullocks is necessary. Two men are necessary on the machine for driving and delivering the sheaves off the collecting board ; six men can tie the sheaves and move them out of the way of the bullocks. Eight acres can be cut in a day with this labour force, though the average done is between 5 and 6 acres. There is thus a considerable saving in cash after allowing liberally for interest on the cost of the machine, depreciation and repairs. The great incentive to the adoption of reapers lies in the difficulty which is frequently found in getting sufficient labour at any price to enable the crop on large holdings to be cut quickly enough. There is little doubt that the machines will be increasingly used in the canal colonies wherever there are holdings of over a hundred acres. In a few villages small holders have attempted to co-operate in the purchase and use of a reaper ; but they have usually failed to work together successfully for very long.

Scythes.

In Europe and America the scythe first replaced the sickle. It is claimed a man can cut an acre with a scythe in a day in temperate climates. In the Punjab, where cutting takes place during warm weather, it may be thought that at least half an acre could be cut. Experiments have been tried, but with very limited success. The posture for cutting by a scythe is not liked, and is said to be very hard. The straw is very slippery, and the gathering of the swath is very difficult as compared to what is the case in Europe. The most successful scythe tried has been

one of the Canadian type, which is smaller than that in genera use in Britain.

As yet reapers are only used in the canal colonies. There the size of the fields is about one acre. And although this is rather a small field for cutting with a machine, yet it does not preclude their use. The machines recommended for this Province will cross the irrigation ridges ("bunds") perfectly well, cutting all the time. Reapers could not be used on land irrigated from ordinary wells. They are not yet used on "barani" lands; it would be possible to do so only where the soil becomes fairly hard by harvest time, and it would probably be necessary to use the "sohaga" after sowing. This is not generally done on "barani" land, and is certainly not permissible unless followed by harrowing. Even so there may be advantages in leaving the surface covered with small ridges, and these would hinder the working of the reaper.

Threshing is carried out in most parts of the Punjab by bullocks dragging over the wheat spread on a hard earth floor a sort of hurdle covered with straw known as a "phalla." Threshing is much more rapid when this is used, and the "bhusa" (bruised and broken straw) is much finer. There are some parts of the Province where the "phalla" is not used, but it seems to be distinctly advantageous. The weather in the threshing season is ideal for the purpose, and it is only occasionally that the threshing is delayed or the grain damaged by bad weather. The straw on the threshing floor is repeatedly shaken up during the process by means of a fork with iron prongs arranged like the ribs of a fan ("trangli.") The grain naturally falls to the bottom, and when threshing is finished, the overlying straw is removed with the same tool.

The final separation of the grain from the broken straw and dust is done by winnowing from a flat basket (the "chhajj") held high over the head. There are frequent steady winds at this time of the year.

Five men and three pairs of bullocks should be able to thresh out 30 or 40 maunds of grain per day according to the proportion between the grain and straw in the crop. Thus the cost of threshing by this method is about annas 2 per maund. The winnowing is commonly carried out by casual labour and menials, who also carry and stack the "bhusa." For all this they are paid a share of the produce, generally one-twentieth, so that the cost at current rates may be reckoned at annas 2½ or 3. And the total cost of winnowing, threshing, and cleaning is annas 4½ or 5.

The Agricultural Department made a fairly thorough trial of steam threshers at Lyallpur and in the neighbourhood. These big threshing outfits are also regularly used by the various military farms and some large landholders in the canal colonies. The cost of threshing by this method has been estimated from the Lyallpur trials as well as it is possible to do. The calculation cannot be regarded as very exact, for the cost per maund of grain turned out depends so much on the average daily outturn and the number of whole days actually worked during the year as well as the amounts allowed for depreciation and repairs. Threshing by these machines seems here to cost at least as much as doing it by hand.

The actual cost will be more or less according to the amount threshed per season. There is also a distinct advantage, which cannot be fully allowed for in this calculation, in that whilst the hand winnowing and cleaning is done mostly by immigrant labourers and menials, the labour connected with the steam threshing is undertaken by the farmers themselves and their servants. Moreover, even at present the extent to which the bullocks and men are occupied in the hot weather with the wheat threshing does tend to interfere with the work of cultivation on the summer crop, although after the sowing of cotton and early fodder there is perhaps less work on the land than at any other time of the year. Increasing intensity of cropping and cultivation will render the advantages of finishing the threshing quickly more important. Storms also often cause heavy damage to grain and "bhusa" lying unthreshed or in heaps, and hence early finishing of the work is important.

There are difficulties in steam threshing in this climate with the ordinary machines, and some of these difficulties have not been fully overcome in the special machines designed for India. Straw is such an important part of the farmers' cattle foods that the breaking and bruising, as is done when it is trodden by bullocks, cannot be dispensed with. Special drums are attached to the Indian models of threshers for thus breaking the straw, with the work of which there is generally not much cause for complaint. But owing to the intensely hot dry weather the grain is very liable to be broken to a certain extent, and none of the machines is entirely free from this defect. The actual percentage broken is not high, commonly about one per cent. if all possible care is taken in adjustment and feeding; but with some kinds of wheat, and also in the early morning, it is very liable to rise to 4 or 5 per cent. This in itself is serious, but it is more so because stored wheat is always liable to considerable damage from the attacks of weevils, and the

presence of broken grains affords food for the insects in stages when they cannot attack whole grain.

Wheat grain is stored in a variety of ways, loose or in bags in rooms, in mud-bins, either box shaped or cylindrical (called "kothis" and "bharolas" respectively.) The latter two methods are useful for small quantities for seed or home consumption, but are hardly applicable to large quantities intended for sale. A custom of storing in pits with sides lined with matting, once common in some of the dryer tracts, has practically died out.

In the main the wheat intended for sale, and especially that intended for export, used to be disposed of as soon as possible. But in parts where the means of transport are not satisfactory, this is impossible; and, moreover, everywhere the strengthened position of the farmers is accompanied by a tendency to hold grain for the later rise in the market price. War conditions have accentuated this, but storing large quantities of wheat in the Punjab is liable to result in the loss of a considerable proportion of the grain through the destruction caused by weevils in addition to that which may be eaten by rats.

Two kinds of insects are commonly recognised as attacking stored wheat, "khapra" and "susri" respectively. The former includes the larva or grub of one insect only (*Trogoderma khapra*), but the latter is used for any small beetle found attacking wheat.

There are actually three insects which do serious damage to stored wheat in this Province. Much detailed information as to their life histories and methods of destruction was elicited by the researches recently carried out at Lyallpur, though further experiments on the efficacy of simple practical methods of prevention of weevil damage are still needed. The correct scientific names of these three insects are *Trogoderma khapra*, *Rhizopertha dominica* and *Calandra oryzæ*. There are important practical differences in the habits of these three.

Trogoderma khapra only attacks grain during the larval stage (when it is known as "khapra.)" It is most active during the hot weather, and ceases to do damage of any practical importance after September; but it works steadily throughout the hot weather. If the grain is stored in a high full room, the proportion of grain damaged is not very great, for the damage is restricted to the top 6 inches or foot, and does not proceed further. In that layer, however, the destruction is often very complete, so that at first sight the heap appears to consist of little

else than dirt, the "khapra" and their cast skins, and half eaten grain, but no flour.

Calandra oryzæ chiefly damages the wheat grain in the adult stage, and in the submontane tracts is the commonest adult insect damaging wheat. It is a true weevil with the usual long snout. It is mostly active in the monsoon period only. It multiplies rapidly in favourable conditions and does much damage, and is generally in moist tracts a serious pest. Grain attacked by this insect may be recognised by the fact that the interior is only partially consumed, the skin being only punctured by small holes. A floury residue is left amongst the wheat grains. The larva lives entirely inside the grain.

Rhizopertha dominica also chiefly damages grain in the adult stage. It attacks grain right through the summer, and is apt to be a serious pest all over the Province. In the dry western parts of the Province this and "khapra" do most damage, whereas in the submontane tracts *Calandra* and *Rhizopertha* are the most serious pests. Very little "khapra" is generally found in the submontane tracts. The damage from *Rhizopertha* is characteristic, for the interior of the grain is quite cleared out, leaving the thin skin riddled by large holes. A large amount of floury matter is left mixed with the wheat. The larvæ live inside the grain. It may be noted further that *Rhizopertha* commonly attacks stored wheat from the bottom as noted in the case of the elevator at Lyallpur and in "thekás" at Panipat. This, however, requires further observation. This is the only one of the three so far found on the wing in grain markets and wheat godowns.

These insects are all winged in the adult stage, and presumably may fly to, and thus infect, clean grain stores. But they are essentially indoor insects, and do not fly about out of doors much. Wheat on the threshing floors has not been found to be infected. It is therefore evident that there will be little chance of attack if the wheat is all taken from the field straight to a perfectly clean store, and care taken not to allow infection from bags or wheat from an infected store. Moreover, it is also evident that infected wheat could be cleaned of weevil by separation with an air blast, since this can be adjusted to remove not only the "susri" and "khapra" which are mixed with the wheat, but also the light grains which are partly eaten out by the contained larvæ. It might be necessary to repeat this process after a few days

to remove those larvæ which have hatched from eggs present at the time of the original cleaning.

Only a very well built, and therefore expensive, store can be cleaned out entirely free from weevil; nor is any sort of fumigation really effective except in such a special building. But there would seem to be a possibility of improvement in the direction of partially effective methods such as may reduce the extent of damage where such absolute measures as those referred to above are not possible. Since the "khapra" only damages the top of the heap, it would seem to be advisable to build stores for as deep storage as possible. It is found that in the monsoon at all events the attack (in this case of chiefly "susri") can be checked by taking the wheat out, cleaning it by hand, or by hand winnower and spreading it in the sun. The cleaning, whether by hand or by the hand power winnower, probably does not ever free the grain from insects in every stage, and the store will still contain a good many when the grain is put back. But a great number of insects are removed by this means, and the rate of destruction thus greatly lessened. The sunning also seems to do good. The exact way in which this sun-drying acts still needs investigation. *Calandra oryzæ*, the weevil which does the serious damage during the monsoon, is said not to damage wheat containing less than 8 per cent. of moisture. This may be the explanation of the benefit of sun-drying, or it may be due to the high temperature.

Seed wheat, if taken straight from the field and put into mud "kothies" which are new, or free from weevil and sealed up with mud, is safe from weevil. Larger quantities of seed wheat can be partially protected by distributing napthalene balls in muslin bags throughout and on top of the grain at the rate of 8 lbs. per 100 maunds. This prevents the wheat from getting damaged throughout, but does always prevent some damage in the top layer. It is also sometimes stated by farmers that the leaves of the "neem" tree are useful in the same way when they can be obtained. Storage in or under the "bhusa" of gram is also said to tend to protect the wheat.

Storing of "bhusa."

"Bhusa" in this Province is stored either in small nearly conical stacks thatched with straw, in low circular stacks roofed with mud, or in low peaked heaps covered with mud, and looking exactly like the English root "clamp." These are known respectively as "kup," "palla" and "dhar." The first method is common in the wetter parts of the submontane tracts; the "palla" in the North-West

districts; the "dhar" is suited only to the driest tracts. There is less wastage and damage from rain in the "kup' than in the others. The "dhar" is the worst in both respects, but it is the easiest to make. A certain amount of skill is required for the putting up of a "palla," as the "bhusa" has to be tightly packed inside a barricade made of the ordinary bedsteads set up on end. The recent high price and keen demand for "bhusa" for the army is causing the "kup" to become the standard method of the canal colonies. The extra labour involved in making a "kup" nstead of a "dhar" probably amounts to less than half an inna per maund.

Roughly the proportion between the yield of "bhusa" and grain in the Punjab is rather less than 1¾ of "bhusa" to one of grain. A few years ago "bhusa," though always valued in the "barani" districts or in the towns, was only worth annas 4 per maund in villages, in districts of plentiful irrigation, or in the riverain tracts. Especially it was cheap in the canal colony villages. But for some years the price has been rising steadily, and this has been greatly accentuated by the army purchases during the war, so that it now frequently sells for a rupee a maund or more in the village. Thus the value of the "bhusa" has become an important part of the total value of the crop. "Bhusa" forms the basis of the bulky food for cattle during the cold weather and early summer mixed with such chopped green fodder as is available. It will readily be understood that the breaking and bruising of the straw in threshing under the bullocks and "phalla" greatly increases its value as a cattle food. This is due to the great reduction effected in the expenditure of energy necessary to break it up by chewing and in the animals' stomach. Thus in a rough experiment at Lyallpur, in which cattle fed on whole straw were compared with those fed on "bhusa," both groups doing light work and receiving no other food, those fed on "bhusa" lost in weight on the average about one pound per day whilst those fed on long straw lost weight at the rate of about three pounds per day.

The surplus wheat of the Province to the extent as a rule of about ½ to 1½ million tons is exported chiefly to Europe. At times, however, the proportion going to the United Provinces becomes considerable.

The export from Karachi is carried on by big exporting houses, who have agents and sub-agents all over the main wheat selling areas. There is no especial centre of this trade: the various "mandis" (organized markets) drawing produce

only from so far as it will come by cart, say 20 miles or so ; and large quantities are despatched from even the smallest Railway stations direct to Karachi. In the "mandis" the trade is carried on by commission agents ("artis"), who rent the market spaces and sell to the best buyer in the interest of the farmer. They take a commission of about 1¾ per cent. from the seller, and this also covers the labour charges involved in weighing and delivery. For the export trade the value of wheat at present depends only on its cleanliness, freedom from admixture of barley, and general condition. White grain is preferred, but rarely any premium is given for superior strength or hardness, so that naturally it is the softest wheat which is exported. At the small Railway stations the grain is bought directly by the firms, who advance 90 per cent. of its price against a Railway receipt, and pay the remainder when the cleanliness has been estimated on arrival at Karachi.

Elevators.

Recently a grain elevator has been put up at Lyallpur by Government, and is now working. Ordinarily Indian wheat is sent to Karachi in gunny bags. The wheat is taken out there and classified and re-bagged for loading on the ships. When it reaches a European port, the bags are broken up and the wheat generally put in an elevator. As will be seen, the handling charges and cost of bags ultimately falls on the producer. If bulk loading was adopted on the railways and ships, the handling charges would be appreciably reduced. This, however, entails erecting elevators at Karachi, and many more in the exporting tracts. Without a comprehensive scheme of this kind there is a limited prospect only for the Lyallpur elevator. The whole question requires thorough investigation by a committee on which railway, shipping and exporting agencies are represented.

Wheat for export to the United Provinces is usually purchased through the "artis" by buyers and agents visiting the Punjab "mandis" specially for the purpose. As already stated, this is a rather spasmodic trade.

There are several big roller mills in the Province and at Delhi, and although the demand by these mills is in itself very inconsiderable in comparison to the total produce, yet they have a greater importance in the market than is represented by the amount they purchase. There is practically no forward trade in wheat, and consequently the mills, or the contractors who supply them, must purchase regularly whatever the state of the market. In addition to these large concerns, which alone are capable of turning out white flour, there are also smaller stone mills driven

by steam, oil, or water power, which assist in supplying the needs *chiefly* of the non-agricultural population. The wheat consumed by the latter is ground between stones either by hand or bullock power. Only the largest pieces of bran are separated by sieving to the extent of 1 per cent. to 3 per cent. of the whole meal; beyond this the "atta," which is the staple food of most Punjabis, contains the whole of the wheat grain.

Cost of milling—4*d*. to 7*d*. a maund.

Cost of hand milling—8*d*. to 10*d*. per maund.

Ordinary wheat is mostly used for bread making, and thus the value of ordinary wheat depends on the amount of flour yielded by a given quantity of grain and the size and quality of the loaf which can be baked from a given quantity of flour. It has already been stated that there are a large number of different varieties of ordinary wheat grown in the Punjab. In fact nearly forty have been so recognised already. These differ in the yield which they will give at all events under any given conditions of soil and watering: in fact the differences in yielding power between some of them seem to hold good whatever the conditions under which they are grown.

Selection works.

The first work undertaken with wheat, and the one to which most attention has been devoted, was the study of these varieties with a view to replacing the mixtures everywhere grown by pure and selected seed of the best variety. Theoretically the best is that one which produces the greatest value per acre. But for the present it is necessary to pay attention primarily to the yield per acre. The quality of the grain can only be of great importance in the case of a wheat which is also a very heavy yielder. For in the local market the premium obtainable for a superior wheat is very small and not very certain. The real value of a superior quality could only be obtained when it was grown so extensively as to gain recognition in the Liverpool market. But it would be unsound, if not impossible, to induce farmers to grow a variety yielding a lighter crop than their own mixture in the hope that in the future, when the area was sufficiently extended, it would be possible to gain a premium in the market which would more than compensate for the lesser yield.

The commoner Punjab wheats were separated in 1908-09, and have now been thoroughly tested. These tests have been carried on at Lyallpur very extensively on large plots under ordinary farm conditions chiefly on land cultivated by the farm tenants. The results are only applicable to the conditions

in the western canal colonies, but for those conditions they are very reliable. The tests have been reduplicated a very large number of times with results quite as consistent as is to be expected in such experiments. In fact it may be doubted if wheat varietal tests have ever been carried out more thoroughly anywhere. For instance two wheats—Punjab 11 and a Pusa wheat (*Pusa* 12)—have been tested one against the other annually from 1913 to 1917, the total number of tests being forty. A statistical examination of the results shows that chances are over 100: 1 that the Punjab wheat will yield better than the Pusa one. The mean difference between the two in the trials is over one maund per acre.

These tests have shown that under ordinary canal colony conditions the wheat Punjab 11 is the best of the common Punjab wheats. This is the type which constitutes the greater part of the mixed wheat crops found on the canal lands, and is probably the chief constituent of all "Karachi white" wheat. It has always been common in the western canal colonies, and periodical surveys have shown that, even apart from the efforts of the Agricultural Department, it was increasing in popularity. But except in the case of crops grown from seed supplied by the Department it is never pure, and there are many fields in which other varieties predominate. The pure variety naturally gives a higher yield than these mixtures, especially as selected seed is distributed. And owing to its freedom from barley and red wheats, the pure grain fetches a premium of annas 2 or so in the market on the ordinary mixed wheat. In 1919-20 the area of pure No. 11 was about 300,000 acres, and will be greatly increased in the near future. The Agricultural Department now sells or superintends the sale of over 1,500 tons of seed annually, and naturally there is also some expansion apart from the efforts of the Department.

The premium obtainable at present for superior quality is only about annas 2 per maund. On an average crop this means then about Re. 1-8 or Re. 1-10 per acre. This will only compensate for a loss in yield of half a maund. For further improvement it is therefore necessary to find a wheat which yields at least as heavily as No. 11, and which is of superior quality. Work in this direction is proceeding steadily. A variety called 8a has been coming into prominence of late as a good yielder, but has so far not proved equal to No. 11 in yielding powers except on poor soils, where it would appear to yield slightly better. In quality 8a is probably slightly inferior to No. 11.

Cost of cultivation and profit from an acre of wheat crop.

Outlay—

		Rs.	a.	p.
		per acre		
Six ploughings, at Re. 1-4-0 each ...	...	7	8	0
Seed, 24 seers	...	2	8	0
Sowing (ploughing and sohagaing* twice) ...	...	3	0	0
Hoeing and weeding once (contract rate) ...	...	2	0	0
Water rate, revenue cesses, etc. (approximate)	...	10	0	0
Reaping	...	5	0	0
Threshing	...	3	8	0
Winnowig and stacking	...	3	0	0
Total	...	36	8	0

Return—

15 maunds of grain at Rs. 4	...	60	0	0
30 maunds of bhusa at 2½ maunds per rupee	..	12	0	0
Total	...	72	0	0

Profit	..	35	8	0

BARLEY.

Natural Order—Gramineæ.

Botanical name—*Hordeum valgare.*

Vernacular name—Jau.

The world's crop of barley is estimated at about one-third the weight of the world's wheat crop. But the acreage of barley in the world is not a quarter that of wheat. In some places (*e.g.*, England) a large area of barley is grown because it can command a high price for malting in the preparation of alcoholic drinks; in others a large area is grown because the climatic conditions are not favourable to the growth of other cereals. Where neither of these causes come into play the area of barley is generally but a small proportion of the cereal area, and much smaller than the area of wheat.

Area.

In all India the barley crop usually occupies seven on eight million acres as against about 30 million acres of wheat. Most of this barley is growr in the United Provinces, where the area of barley is nearly as great as that of wheat. The area in the Punjab is commonly rather over a million acres, or about 4 per cent. of the total area of all crops, and only about $\frac{1}{9}$th of the wheat area. It is chiefly grown in the districts of Hissar, Ferozepore and Gurgaon.

Small areas of barley are grown in most districts. The geographical distribution of barley is chiefly governed by the climatic conditions; this crop has the shortest growing period of any "rabi' cereal, and except for its liability to damage from frost is the hardiest of all.

Conditions where grown.

Barley is everywhere regarded as a crop for growing on light soils. In the Punjab it will grow well on soil that is too light for wheat, and it will also give a crop where the soil moisture would be quite inadequate for wheat. It is thus grown mostly on light unirrigated land, or on land which the farmer may or may not irrigate according to circumstances.

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* Sohagaing means dragging a plank over the ground to break up clods of earth and to cover the seed.

Barley can be sown at the same time or even earlier than wheat, but it can also be sown later. In parts of the Province where only small areas of barley are grown, it is sown chiefly on fields which are ready too late for wheat to be sown with very good prospects. It is thus often sown as late as December or early January.

The seed rate for barley should be heavier than for wheat; in most districts it is 28 or 30 seers per acre.

Barley ripens earlier than wheat; in most parts of the Province it is cut in the first days in April.

In the chief barley growing tract of the Province it it usually grown mixed with gram on light soils, and with wheas on the heavier land. These mixtures are favoured from the point of view of insurance against extremely dry winters; for gram will succeed where barley will practically fail for want of water, and barley occupies much the same position in regard to wheat. The question of the soundness of the practice of growing these mixtures needs local experimental investigation. There is little doubt that many farmers have a very exaggerated idea of the increased yield obtained by this practice of growing one acre of mixture as against growing half an acre of each crop. And it must be remembered that when the grains are not separated by the farmer, but are sold in a mixed state, the seller is always and naturally liable to get considerably less for the mixture than he would for the same quantity of grain after separation.

Gram and barley, though grown mixed, can easily be separated for sale either by harvesting separately or after threshing; and in point of fact the farmer generally sells them more or less perfectly separated. But wheat and barley when grown together are not so easily separated, and the grower often sells a mixture in which the barley content may be 30 per cent. or 50 pet cent. Although the exporting firms are generally trading in barley and wheat at the same time, and although it costs comparatively little to separate the two at Karachi, where elaborate machinery has been installed for the purpose, yet it is natural that the price obtained for the wheat is depressed by the presence of the barley. For one thing the buyer may lose through deliberate or unavoidable mistakes in the estimation of the proportion of barley by his staff. Moreover, the mixture is even less favoured by other buyers than the exporters, who have no machinery for a proper separation of the two grains. It is a matter for actual investigation as to whether the gain in yield which results from sowing mixtures compensates for

the depression of the price which results from them. Prior to such investigation a final opinion cannot be formed.

In other parts of the Province there is often admixture of barley in the wheat fields to the extent of less than 10 per cent. For this there seems no justification, for such an admixture can have no value for an insurance, and the exporting firms in such cases pay for the barley only half of the wheat price. This impurity certainly entails loss to the grower, and can hardly be really to the interest of the buyers. In the canal colonies, especially the Lower Chenab and Lower Bari Doab Canals, the purity of the wheat crop has been very greatly improved chiefly as a result of the work of the Agricultural Department, which has distributed or controlled the distribution of several thousand tons of pure seed during the last few years. To ensure pure wheat in the colony markets, however, it is desirable that all buyers, including the exporters, should calculate their prices on the assumption that the wheat will be pure and make deductions for any admixture of barley. At present the rates generally quoted in the markets are for wheat containing 2 per cent. of barley; and though it is true that a bonus is given for purity beyond this basis, such a bonus will seldom reach a small grower. If market rates were calculated on a pure wheat basis, there would certainly be further improvement in the freedom of the colony wheats from barley.

It has been said above that barley in the Punjab is usually grown on fields where wheat could not be expected to yield well, so that the yields obtained from these two crops can hardly be compared. There is, however, little doubt that even on good land and with enough water wheat would not yield so heavily as barley in this Province as elsewhere in the world.

The price which barley fetches in the market depends chiefly on the purpose for which it is bought. In different parts of the world it is used for three purposes—(1) malting; (2) for food for animals; (3) for food for human beings.

In the process of malting the barley is caused to sprout slightly, during which process the starch in the grain is changed to sugar. By subsequently fermenting the "malt" of sprouted grains the sugar is further changed and alcohol is produced. In malting the first requirement of the grain is that it should have a very high "germinating capacity" (*i. e.*, a high proportion of living seeds capable of sprouting), and that the grains after

moistening should all germinate equally rapidly. Assuming equal germinating capacities the relative values of two samples of barley are usually considered to be in proportion to the relative contents of starch. As a matter of fact very little has actually been established by experiment as to what governs the malting value of different barleys. The only measurable characteristic, obviously of importance in a malting barley is the germinating capacity. Ordinarily buyers are guided by the appearance of the grain, it having been found in humid climates that a plump grain with thin transversely wrinkled skin, floury interior, and bright yellow colour is the most suitable for malting. In Europe these characteristics are seen only in barley grown on light soil in a dry season. Barley suitable for malting can be sold in England at a price equal to that of wheat, and sometimes higher. The suitability of Punjab barley for malting is thus a matter of some importance and worthy of investigation. Punjab barley has not the appearance which is favoured in Englaud for malting barley; but, on the other hand, it has a high germinating capacity, and has a good reputation among Indian brewers. There is some reason to believe that (before the war) it was coming into higher favour in Europe for malting purposes, since the exporting firms here were sometimes paying more for barley than would appear to be warranted by its value for feeding purposes.

The relative feeding value of barley is not greatly different to that of gram or cotton seed. But it differs from these in being more starchy in nature, and in this respect more nearly resembles maize. It is thus more suitable for working cattle than for cows or buffaloes or growing animals, though there is no objection to its use for any of these. Crushed barley in the Punjab often forms the basis of the ration of grain for full grown horses, other grains being mixed with it according to circumstances. In western countries barley is fed chiefly to fattening pigs and cattle. For feeding purposes the price of barley is usually about two-third that of wheat.

Barley is everywhere regarded as inferior to wheat as a food for human beings. This is due chiefly to the fact that barley flour cannot be made into bread, though a comparatively small proportion of barley flour can be mixed with wheat flour for bread making. In some European countries this has always been a common practice. It is not a common practice in the Punjab. For flour making there is a further disadvantage attaching to barley in that it is more difficult to separate the flour from the husk, and the amount of bran is higher.

RICE.

Natural Order—Gramineæ.

Botanical name—*Oryza sativa.*

Vernacular name—" Dhan, Chawal."

Area—830,000 acres* for the quinquennium ending 1916-17d

This crop, while occupying 40 per cent. of the nett croppee area of food grains in India, is relatively unimportant in the Punjab, where the area is generally less than 9 lakhs of acres, or a little over 1 per cent. of the rice acreage of India.

In the Punjab it is mainly grown in Kangra, Gurdaspur, Amritsar and Gujranwala. The plant grows best in heavy soil, where plenty of water is available. Stagnant water is, however, unfavourable to its success.

Sowing.

The crop may be broad-casted in the field or sown in a nursery and transplanted. The latter practice is in vogue where irrigation is available, and is considered superior to broad casting. The nursery is sown in June and plants transplanted in July in soil covered with 2 or 3 inches of water, and which has received from 3 to 5 ploughings. It is harvested in September. Three " marlas " of nursery sown with six seers of seed is sufficient for one acre of transplanted seedings.

Water requirements.

Under irrigation rice is estimated to require about 60 inches of water.

Harvesting.

The crop is cut by sickle as in the case of wheat. It is generally threshed by beating with a stick. Sometimes the ears are separated and grain trodden out by cattle. The straw will not break up into bhusa like wheat or barley.

The husk remains attached to the grain after threshing. It is separated by pounding with a pestle in a mortar (" ukhli, mohla). About 60 or 70 lbs. of grain is obtained from 100 lbs. of unhusked rice (" dhan ").

The yield per acre varies from 15 to 30 munds.

*Agricultural Statistics of India.

The cost of cultivation is estimated as follows :—

Broadcasted.	Rs.	a.	p.	*Transplanted.*	Rs.	a.	p.
2 ploughings ...	2	8	0	4 ploughings ...	5	0	0
2 harrowings ...	0	12	0	2 harrowings ...	0	12	0
16 seers seed ...	1	8	0	6 seers seed ...	0	14	0
Sowing ...	0	8	0	Preparation of nursery	3	0	0
2 weedings ...	4	0	0	Manuring ...	1	0	0
Reaping ...	2	8	0	Transplanting ...	3	0	0
Threshing ...	2	8	0	2 weedings ...	4	0	0
Cleaning ...	0	12	0	Reaping ...	2	8	0
Rent ...	6	0	0	Threshing ...	2	8	0
				Cleaning ...	0	12	0
Total ...	21	0	0	Rent ...	10	0	0
				Water rate ...	6	4	0
				Watering ...	1	0	0
				Total ...	40	10	0

Outturn in case of broadcasted is equal to 15 maunds and in transplanted 20 to 25 maunds. The straw is worth Rs. 6 per acre. Gross receipts vary from Rs. 66 to Rs. 106.

Rice straw is used for feeding purposes, but is not valued owing to its toughness and low nutritive value. Rice grain is starchy as compared to wheat or barley.

CHAPTER XI.—COTTON.

Natural Order—Malvaceæ.
Botanical name—*Gossypium herbaceum.*
Vernacular name—" Kapas "

Area and proportion to other crops.

The area of cotton grown in the Punjab has been liable to considerable variation in the last few years owing to the great fluctuations in its price. Before the war the area was commonly about one and-a-half million acres; in 1913-14, a record year, the area reached 1,800,000 acres; there is no doubt that if the present high price, or anything approaching it, is maintained, the area will be increased to an average of two million acres.

Irrigated and barani cotton.

Excepting the montane and submontane areas cotton is grown wherever irrigation is possible and the land not excessively sandy. In the Punjab cotton is almost exclusively an irrigated crop. Four-fifths of the crop is normally irrigated, and it is only in the extreme south-east of the Province that a moderate yield is sometimes obtained without irrigation. The season in the Punjab is much shorter than in other provinces on account of the cold winter, and unless the crop is grown early by means of irrigation water, it can never yield well. The best yields are obtained in the south-east districts (Karnal, Rohtak, etc.) and in the western canal colonies.

Yield.

The average for the Province may be taken at five maunds of "kapas" or seed cotton per acre, which, when ginned, will yield about one-third of lint or fibre and two-thirds of seed. So that the total yield on the pre-war average area may be taken as being about 7,500,000 maunds of "kapas" or 2,500,000 maunds of lint (equivalent to 500,000 Indian bales of 400 lbs. each). And it may be expected that in the future the average total crop may be about 10,000,000 maunds of "kapas" equivalent to more than 650,000 bales of lint. It must be remembered that the whole of this amount does not reach the ginning factories, for the total amount kept for ginning and spinning by hand in the villages is very large, though it tends to decrease.

Local consumption.

The average so used is estimated at 450,000 maunds or 500,000 maunds of cleaned lint corresponding to 100,000 bales; but the amount withheld from the general market varies very greatly from year to year according to the fluctuations in the prices of cotton and also of piece-goods.

Ten rupees per maund is probably an exceedingly low estimate for the average price of "kapas" during the next few years, the present price* being about double this. So that the value of the cotton crop of the Punjab at present and in the near future must be upwards of ten crores of rupees (Rs. 10,00,00,000). Although the area of cotton in the Province is proportionately not great (only 5 per cent. or 6 per cent. of cropped area), yet economically, from the point of view of the income derived from it by the growers and those connected with the handling of the produce, this crop is second in importance only to the wheat crop. The Punjab normally produces 10 per cent. of the cotton outturn of India.

Comparison of yields with other countries.

The yield of lint per acre in various parts of the world on the average from 1913-14 to 1918-19 as given in the Indian Cotton Committee's Report, page 171, is as follows :—

America	185 lbs.
India	80 „
Egypt	365 „
Punjab	130 „

It may be taken that in the canal colonies the yield generally averages 6½ maunds of seed cotton or 170 lbs. of lint per acre.

There are two main classes of cotton grown in this Province the "desi" (country) cotton, which is itself a mixture of varieties, and American, which is a comparatively recent introduction. These varieties are very different in appearance, the American being a bushy plant, whilst the Indian cotton plant is tall and slender.

There are also considerable differences between American and Indian cotton from an agricultural point of view, of which the most important is that the American cannot be sown so late as the country cotton. American cotton should be sown in April, though in some parts sowings can be continued during May. Country cotton should be sown at the same time as far as possible, but it can be grown successfully if sown in the first half of June.

Soils suitable.

Cotton does not succeed on very sandy soil, but it can be grown on any class of soil, excepting only the very lightest. It is a crop which gives a good return for manuring, or rather if grown on manured land. For the cotton crop is very seldom manured directly, but is often grown on land which has received a heavy dressing of farmyard manure for some previous crop. This seems to be the better method. An average crop on unmanured land may be about 5

to 7 maunds per acre. The yield from cotton on land previously manured for maize or sugarcane may be twice, or more than twice the above amount; but such a heavy crop can hardly be obtained by direct manuring. The reason for this necessity for manuring the cotton indirectly is not very obvious; but the explanation probably lies in the fact that during May, June, July, and in a dry year, even in August too, the soil in a cotton field is but very little shaded from the sun and irrigated only at long intervals, so that in the hot dry weather which prevails during those months the upper soil becomes extremely dry. These are the ideal conditions under which farmyard manure can be rapidly wasted or "burnt" out of the soil (by oxidation and denitrification) The only circumstances under which cotton is generally manured direct are when it follows a wheat crop. Such cotton is always at a disadvantage, for it is late sown and is on dry and temporarily exhausted soil. The only hope of getting any good return from such cotton is to manure it, and to water it rather more frequently during its early growth. It must not be thought from the above that the cotton crop is always grown on rich soil. It generally is when grown on land irrigated from wells, but in the canal colonies cotton is often sown on land which has not been manured at all, or not for several years.

Yields on good soil.

One of the reasons why cotton responds so well to the effect of any manurial residues in the soil is the fact that it is almost invariably sown in land which has been fallow for but a few weeks at the most. The best cotton is that sown after "senji" following "maize." The "senji" is removed in the latter part of February or in March. Both on canal land and land irrigated from wells cotton is sometimes sown after sugarcane, and wherever a relatively large area of cotton is sown, some of it will usually have to be sown after wheat. In the canal colonies a great deal of the cotton follows "toria," in fact when "toria" is fetching a good price more than half of the cotton will follow this crop. Sugarcane is removed from the soil chiefly in January and February, "toria" in January, and the wheat harvest starts in mid April. Since the cotton must be sown in April or nearly May, it is evident that none of the soil is fallow for any long time before the cotton is sown, and when cotton follows wheat, it has to be sown as soon as ever the field can be cleared. Cotton does better after gram than after wheat, provided, of course, that the soil on which the gram was sown is suitable for cotton, which it

Reasons for cotton requiring land in good condition.

Practice in the canal colonies.

generally is not, since on irrigated land it is only profitable to grow gram on land which is too sandy to carry wheat.

Number of ploughings.

The land on which cotton is to be sown seldom receives more than four ploughings, and often only one or two. The only exception is when cotton follows sugarcane : in this case the soil has to be ploughed and broken with the harrow to disintegrate the sugarcane stumps.

Preparation of seed for sowing and seed-rate.

Cotton seed has to be prepared for sowing by "leeping" it. This is done by rubbing the seed either on the wet ground or in cow-dung. The object of this is to remove or paste down the fibres remaining on the seed, and thus allow the seeds to be separated one from the other. Seed from the first and the late pickings is not used, as it is liable to be unsound and poorly developed. The best cotton seed has usually a germination capacity of only about 70 per cent. The usual seed rate is 4 or 5 seers per acre. The seed rate is slightly increased if there is reason to believe that the seed is inferior in germinating capacity.

Sowing.

The land is always irrigated just before sowing. If the seed is to be sown broadcast ("chhatta"), the land is ploughed once with the country plough as soon as it is dry enough. Before sowing cotton the soil should be allowed to dry no more than is necessary to enable the bullocks to get into it for ploughing. A delay of a day may cause less satisfactory germination. The seed is broadcasted after this ploughing and the land again ploughed, and then the "*sohaga*" is used. The second ploughing may be omitted ; or more commonly, if time presses, the seed is first broadcast, and the land then ploughed and levelled with the "sohaga."

Harrowing after sowing very beneficial.

A frequent cause of loss in cotton sowing is the thin crust formed as the result of the light showers of rain which *often occur at this time of* the year. Practically every year a certain percentage of the cotton area has to be resown on this account. This means a waste of water at a time when it is badly needed as well as making the crops late. Very little resowing need be done by a farmer who possesses a light harrow, such as the Bar harrow recently introduced by the Agricultural Department. The showers which occur at the cotton sowing period are usually quite light, and would not be sufficient to cause a troublesome crust to form if it were not that the surface of the soil is already much compacted

The Bar harrow.

by the "sohaga." Experience at Lyallpur has shown that any crusting which occurs on harrowed land is generally insufficient to do any harm, whilst adjoining fields left without harrowing are so badly crusted that a zemindar with only the ordinary implements would have to resow them. When a crust forms on the soil immediately after sowing, and if the rain is very light, so that the soil dries very quickly, then the "sohaga" can be used very lightly and tilted upwards, and will break the crust without doing any great damage. But if the plants have started to germinate, then the "sohaga" is useless and the ordinary farmer is helpless.

Uses of the Bar harrow for cotton.

The harrow should be used directly after the "sohaga"; it should not be used instead of the "sohaga" for covering the seed, for the "sohaga" fulfils an important function in levelling the soil; and also the use of the two implements leaves a much better surface. The extra cost is not more than two or three annas; for an acre can be harrowed in a couple of hours. The harrow should also be used to break the crust if any forms. It can be used before the seed germinates, or as soon as the plants are a couple of inches high. It is only when the majority of the plants are just appearing above ground that the harrow will do any serious damage. It can thus often be used when the "sohaga" cannot, and it always does better work. If there are any weeds appearing, or if the field has to be irrigated, the field can be harrowed again until the plants are nearly six inches high without their suffering any appreciable damage.

Cotton sown broadcast.

In the Punjab cotton is everywhere always sown broadcast, with the exception of some 20,000 acres sown in lines by zemindars who have adopted the practice at the instigation of the Agricultural Department. There is probably no great objection to this practice on well irrigated lands. For there the size of the fields is so small, and they are further sub-divided into such very small compartments for irrigation, that the subsequent hoeing must be done by hand. On the well lands the soil is, moreover, generally maintained in very good physical condition all the time. The cultivators who have colonized the canal areas still follow their old fashion although it is very unsuited to their new conditions. The cultivator on the canal lands sows a much larger area of cotton. And

Disadvantages of broadcast sowing.

he sows it, as has already been seen, on land from which the previous crop has very recently been removed, and which is thus in very poor condition. If the crop is sown broadcast, it can

only be effectively intercultured by hand, which is a very expensive method. In point of fact it is never intercultured effectively, and the yield suffers in consequence.

In the canal areas broadcast cotton is often partially intercultured by ploughing between the plants with the native plough as well as this can be done without unduly injuring the plants. This is not done until the plants are quite big, usually in July. This does not cost much (say one rupee per acre per ploughing), and does a certain amount of good. But it cannot be done often enough, or well enough, to be really effective in cultivating the soil without doing any excessive amount of damage to the plants.

Cost of interculture of broadcast field.

Sometimes in the ordinary practice cotton fields are hand-hoed once This is effective so far as it goes. But this operation is expensive, the average cost being upwards of Rs. 3 per acre. And as it takes one man upwards of five days to hand-hoe one acre with the "khurpa", very few fields are ever hoed more than once.

Line sowing and interculture: its effect on yield.

If, on the other hand, the cotton is sown in lines, then it can be frequently and effectively intercultured at a very low cost. The effect on the yield is remarkable. The average difference in comparisons at the Lyallpur Experimental Farm in four years is 3 maunds. In these experiments the broadcast plots are ploughed at least once with the country plough and receive at least one hand-hoeing. They are thus treated as thoroughly as any farmers ordinarily do. The cost of the interculture on these broadcast plots is upforwards of Rs. 3-8-0 per acre. The plots sown in lines are hoed with a bullock-drawn hoe at least once after each rain or irrigation until the plants are too big for it to be possible. This will be until about the middle of August as a rule. The number of hoeings will be about six on an average, though sometimes it may be as many as twelve. A man and a pair of bullocks can interculture four acres of cotton in a day, so that the cost of eight hoeings with a bullock-drawn hoe is less than that of one hand-hoeing with the "khurpa".

Distance between lines.

Experiments at Lyallpur indicate that there the optimum distance between the rows of 4 F. American cotton is three feet; and two feet only for country cotton. These distances are really the best only on average soil; on very good soil the distances can be increased in the case of American cotton to four feet.

Cotton can be sown in lines either by "kera" behind the native plough, as is commonly done with wheat, or by means of the drills introduced to this Province by the Agricultural Department. These drills, the use of which has been described in a previous chapter, sow two rows at a time and also allow of more accurate work. Whichever is used, it is advisable to affix iron marker to indicate the position for the next row.

Method of line-sowing, Lyallpur drills.

It is difficult to give precise simple instructions for the watering of cotton owing to the great variation in the amount of rainfall during different seasons, and also the difference between the water-holding capacities of the different soils on which it is grown. The following account will, however, give an indication of what appears to be best practice on average soils in the complete absence of any rain.

Watering of cotton.

If the germination of the seed is very poor, it may be necessary to irrigate only a week or two after sowing in order to allow of the gaps being resown. This should not be done if it can be avoided as, apart from the resowing, it appears to do no good. Otherwise American cotton sown in March or April will need about three waterings before the end of July, that is it needs watering at intervals of four or five weeks. Experiments at Lyallpur tend to show that two waterings before mid July are ample. During the next six or seven weeks in the absence of rain at least three waterings may be given with advantage at intervals of 14 or 18 days. This carries the crop on to about the middle of September. After about another month a last watering appears to improve the quality of the fibres of the last pickings, even if it does not greatly affect the weight of the yield. Country cotton will receive just about the same irrigations, except that the last watering is less necessary; but in this case it is usually given for "senji" sowing. With either kind of cotton slightly longer intervals are permissible during the early part of the season if the crop is in lines and frequently intercultured.

Frequent watering during flowering period.

Naturally any of these irrigations may be replaced by rain; and on good soil the crop will not suffer greatly, perhaps not at all, from a further extension of the intervals between irrigations. On the other hand, if cotton is sown on sandy soil, it will not do well unless irrigated more often than here suggested. The reason that more frequent irrigation is advantageous during August and the earlier part of September is that that is the time when the flowers appear. For a large number of flowers to be

formed growth must continue steadily and rather rapidly during all the flowering period. Primarily the final yield depends on the number of flowers formed, so that sufficient water must be given for the steady and rapid growth necessary for the appearance of a large number of flowers. A crop directly manured is said to need a greater number of watering.

Picking.

Picking of the ripe cotton starts early in October in the case of American cotton; a week or so earlier in the case of country cotton. The greater part of the crop is picked during November. Pickings of American cotton go on until the last bolls are killed by frost in January. With a heavy crop of country cotton the pickings go on almost as long; in a poor year the pickings finish in December. The picking is done chiefly by women, children and menials. The crop is picked at very short intervals, not more than ten days during the middle part of the season, when the bolls are opening in greatest number: the total number of pickings is as large as six or seven. Such frequent pickings could hardly be profitable but for the cheapness of the labour employed. The pickers are paid by a share of their picking. The share given depends on the amount of cotton on the plants ready for picking at the time. In the case of the first or last pickings, when there are only a few pounds to be got off an acre, the proportion paid may be as high as a quarter, or even sometimes a half. During the middle of the season the proportion is one-tenth or even one-twelfth. The proportion of the whole crop given to the pickers is reckoned to be at least one-tenth, and is probably often as much as one-eighth. The cost of picking comes to about two-thirds of what is paid in Texas in the United States of America.

Cost of picking.

Leaf in picked cotton.

The cotton leaves become so exceedingly brittle in the dry atmosphere of the Punjab that the picked cotton unavoidably contains a certain amount of broken leaves. This spoils the class of lint, and is a continual cause of complaints from the cotton trade. But there is little hope of any great improvement in this direction, for the picking is not very careless in this respect. If the cotton is picked more free from leaf in other countries, it must be because the leaves there are less brittle. There is, however, some carelessness in the matter of mixing with the clean cotton, the stained locks off the ground or off the bush, and improvement in this respect is possible. In the latter part of the season some seed cotton is brought into the markets

Mixing.

containing more moisture than it should. It is often said that cotton in the villages is placed in water-courses or in damp rooms deliberately so that it may absorb moisture. This possibly does occur, but it is certainly not very common. For one thing it is unnecessary. In the latter part of the cotton picking season the dews are heavy in this Province, and the pickers generally do not start work until late in the day in order that the cotton may dry before being picked. If it is desired to have the cotton moist, it is only necessary to start picking a little earlier. There is undoubtedly carelessness in not drying cotton after picking, and this is the chief cause of the damp cotton, or cotton deteriorated by damp storage, which is found *in some market. At the same time it must be remembered* that the bulk of the seed cotton coming into most of the Punjab markets comes in very fair condition, and that the remedy for any carelessness lies in the hands of the buyers if they will differentiate fairly between lots of varying cleanliness. Actually deductions from the price on account of dirt or damp are commonly made by the ginners who buy the seed cotton; but in many places these deductions are not in very strict relation to the class of the different lots, so that they have little educative effect.

Damp kapas.

Responsibility of buyers.

In this Province almost the whole of the seed cotton is bought by the owners of the local ginning factories, who sell the lint after ginning either to the local representatives of the exporting firms or mill owners, or in Bombay through brokers. As a rule the greater part of the lint is sold locally. The local sales are generally of loose unpressed lint, but the seller has the right to press it in his own machine at a standard rate. The gins most commonly used are the single roller type, generally Platt's; there are no saw gins* working in the Punjab, and only a few double roller gins. The ginning is not as carefully done as it might be. The presses, however, are of the best, and the pressing is efficient. The Indian bale weighs 400 lbs. inclusive of the tare (sacking and iron bands). The average dimensions are about 4 feet by 18 inches, and a density of 45 lbs. per cubic foot as compared to 23 for United States of America and 35 for Egypt. The sacking and the iron straps weigh 7 or 8 pounds.

Sale of kapas and cotton.

The Indian bale.

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* *One factory has been working saw gins in the season 1920-21.*

Sale in Bombay.

Cotton in Bombay is sold on the basis of a "candy" of 784 lbs., *i.e.* two bales exclusive of tare. The costs incurred in ginning, pressing and sending the bales to Bombay and selling it there are somewhat difficult to estimate, for some items are reckoned as a percentage on the price, and therefore vary with the fluctuations. The following will indicate approximately the scale of these charges as they were in the season 1917-18 :—

		Rs.
Freight to Bombay per "candy"	...	22
Pressing two bales	...	19
Insurance, brokerage, interest, etc.	...	6
Total charges on lint per candy	...	47

One "candy" is practically 9½ maunds, so that the local price for loose lint corresponding to the Bombay price for pressed lint can be calculated by deducting Rs. 47 and dividing by 9½.

Thus if lint was worth Rs. 650 per "candy" at Bombay, the corresponding price of per maund of lint at Lyallpur should be (650 − 47) ÷ 9½, *i.e.*, 603 ÷ 9½, or about Rs. 63-8.

Rates for ginning.

The proportion between lint and seed in the seed cotton is about 1 : 2 ; so that before dividing the local price of lint by three to get the price of seed cotton we must deduct the cost of ginning three maunds of cotton and add the value of two maunds of cotton seed. In 1917-18 the rate for ginning the three maunds came to Rs. 3 and the value of the cotton seed to Rs. 7-8, so that Rs. 4-8 had to be added to the local price of lint. Thus if the local price of lint is Rs. 63-8 per maund, to get the price of seed cotton corresponding to this on the basis given above we have to add Rs. 4-8 and divide by three ; this gives us the local rate of seed cotton to be Rs. $\frac{68}{3}$ or Rs. 22-10-8.

Calculation of price of kapas from Bombay quotations.

Roughly the Bombay price for a candy of lint is about 29 or 30 times the corresponding local rate for a maund of seed cotton.

A small part of the crop is bought in the form of seed cotton by exporting firms or mill owners when they have hired a ginning factory ; but, as already explained, the bulk of it is purchased by the ginning factory owners who sell the lint usually immediately either locally or in Bombay. As the freight on loose seed cotton is high, and it is a material which is

liable to damage in transit by rail, the gin-owners at any particular station have a decided advantage over any other buyers in the market for seed-cotton in their neighbourhood. They have not really a monopoly, for if the price in any particular station is depressed beyond a certain degree, many sellers take their cotton by road to a better market. Moreover, the ginners have never been able to combine to cut prices to any great extent.

Disadvantages of Factory buying of American cotton.

Even with country cotton there were objections to this trading by the ginners, for they look to make their profit more from a big turn-over on low capital and other expenditure than from obtaining the top price for the best quality of product However, the country cotton was such a cheap cotton and of such poor staple that the only point to which much regard was paid was its class, *i.e.*, colour and cleanliness. Thus the final buyers had no difficulty in judging, so that the system of ginning by middle men buyers had not such serious disadvantages.

Mixing difficult to recognize.

With the American cotton, however, the case is very different. This cotton has a much longer staple, and its price is greatly lowered by any appreciable admixture of the country cotton. And it is difficult for any buyer certainly to detect an admixture of, say, 5 per cent. of country cotton in the ginned American lint; it is impossible for any one to estimate the degree of admixture by judgment or by any simple test. A buyer experienced in the local trade may be able to detect an admixture of 10 per cent. of country cotton in the American lint; but no one could say with the slightest certainty if that mixture is 5 per cent., 10 per cent., or 15 per cent. The difference between the values of lots with varying admixture is only seen in the spinning mill. But there is little difficulty in separating the country cotton from American if it is seen before it is ginned. Therefore the only way for buyers to trade in American cotton with any certainty of getting the pure staple is to buy the seed cotton and have it ginned themselves. The local gin-owners will not as a rule gin for other buyers, so that mill-owners or exporting firms will only be able to purchase American cotton satisfactorily in the Punjab if they buy or build or lease factories here. One or two firms have recently bought ginning factories, and this may eventually force the local gin-owners into undertaking contract ginning, as is common in most parts of the world; so that the marketing conditions here should improve in the course of a few years.

The fact that American cotton is now grown in the Punjab on a very large scale is entirely due to Government action. The creation of the big perennial canals by the Irrigation Department made a large area of country suitable for this crop. The Agricultural Department has fostered and advocated the growth of this crop in face of considerable difficulties, until it now constitutes the bulk of the cotton crop in the western canal colonies (which afford the most favourable conditions for the growing of this cotton), and is spreading into other districts.

Credit for introduction of American cotton.

In 1902, when the Agricultural Department first acquired a little land for experimental purposes, American cotton has been growing in the Punjab for many years, having been introduced apparently long before that date. But in 1902 this cotton, was represented by occasional stray plants in the country cotton, and possibly a few minute areas, in which it formed a more important part of the mixture. The fact of the presence of these plants was probably known to no one except the growers in whose fields it appeared, and possibly to a few ginners. In 1902 the Department started trials with cottons imported from other provinces and countries. These continued without much definite progress until the time when trained experts were appointed to the Department—1906-08.

History of introduction of American cotton.

Then two definite lines of action were immediately initiated. These were respectively the testing of the different strains found in the seed collected from the stray plants in the local crops and at the same time the popularisation of the crop by the distribution of imported seed, and, above all, by the organization of the sale of the produce, so as to obtain for it the premium over country cotton which it ought to command. At first various methods were tried without much success, though by the organized sale some premium was always obtained, whereas none was obtainable in the open market. Finally auction sales were organized by the Department on co-operative lines. Still great difficulty was experienced, for few buyers were interested, and those who were found themselves hampered by the unsatisfactory state of affairs in regard to ginning already described. However, the growing of this cotton gradually spread; it received a distinct impetus in one or two years, when the crop was badly attacked by bollworm or damaged by heavy rain, from which American cotton suffers less than the country variety. In 1913 the area of American

Selection and distribution of imported seed.

Auction sales.

cotton in the Province was estimated at 30,000 acres. There is no doubt that early progress was greatly hindered by the practice of importing seed from Bombay (Dharwar) instead of distributing local seed; for plants from the imported seed were not hardy against Punjab conditions. Actually the most of the area referred to above was grown from seed kept by the farmers themselves from year to year; the chief reason why progress was slow was the fact that no important premium could be obtained for the produce.

Importance of using local seed.

In 1913 the seed of a selection 4 F. from the original Punjab stray plants was distributed. This, being a pure line selection, naturally carries a more uniform fibre, and it is a hardy heavy yielding strain. The war starting just before the season of 1914 removed the difficulties in commanding an important premium for this cotton. For in the selling season of 1914 the price of country cotton was very low down to and even below, Rs. 4, due largely to the fact that this cotton was chiefly used on the continent in Germany, Austria, Italy, and Belgium. There was, however, some demand for the American cotton for use in Indian mills, and thus it fetched Rs. 6 to Rs. 7, a very important relative difference. Thus in 1915, although the area of all cottons sown was naturally at a minimum, yet the proportion of American was much higher. Since that date the very high prices commanded by the American lint, for which there is a keen demand both in India and Japan, has caused the area to increase very rapidly.

4 F. American cotton.

The figures of the area of American cotton for the last few years have been as follows:—

Rise in area of American sown.

*1902-05	...	300 to 500 acres only.	
1911	...	10,000 acres.	
1913	...	30,000 ,,	of which 400 acres 3 F and 100 acres 4 F.
1914	...	60,000 ,,	of which 2,600 acres 4 F.
1915	...	70,000 ,,	of which 7,700 acres 4 F.
1916	...	140,000 ,,	of which 30,000 acres 4 F.
1917	...	176,941 ,,	of which 120,000 acres 4 F.
1918	...	390,000 ,,	of which bulk was of 4 F. type.
1919	...	525,000 ,,	

* Indian Cotton Committee's Report and figures from Lyallpur Farm.

It will be seen, therefore, that as late as 1913 there were 30,000 acres of American cotton, of which only 2,600 was of the 4 F. type. After 1917 the bulk of the American cotton was of the 4 F. type owing to the large sales of seed by the Agricultural Department.

Classification of country cotton.

The country cotton of the Punjab is a mixture of several varieties classified by Mr. Gammie as follows :—

Gossypium sanguineum.—The stems and the veins of leaves are deeply tinged with red colouring matter. The flowers are pink or deep reddish purple in colour. There are varieties with leaves having narrow lobes and also varieties with broad-lobed leaves. This cotton is apparently very hardy, withstanding a hot dry climate. It forms an important part of the mixtures of country cotton grown in Multan, Jhang, and the neighbouring country. The cotton from this part of the Province enjoys a high reputation on account of its bright colour. Some strains at least of this red-flowered cotton have as long lint as of the indigenous cottons in the Punjab. The average length of the best strains is at least 0·8 inch.

Gossypium indicum.—This is devoid of the red colouring matter, and has comparatively broad-lobed leaves and yellow flowers. It constitutes the chief component in the mixture in Lahore, Amritsar, and the canal colonies. It is known to local farmers as "desi" cotton. It yields perhaps the longest and finest lint of any of the Punjab local varieties; but neither the colour nor the ginning outturn ("kan" or proportion of lint in the seed cotton) is very good. The latter is seldom much over 32 per cent., and in some years falls to 30 per cent.

Gossypium indicum : Var. Mollisoni.—The plant is similar to the last mentioned variety, but has white flowers. The lint, however, is very different, being short, hard, coarse and rough. The ginning outturn is very high, frequently approaching 40 per cent.

Gossypium neglectum.—With narrow-lobed leaves and yellow flowers. This does not constitute any very large part of the mixture in any part of the Province.

Gossypium neglectum : Var. roseum.—Similar to the last, but having white flowers. This is the most important constituent of the mixture grown in the south-east of the Province, and is often called Hansi cotton. The lint is similar to that of the other white-flowered variety (*Mollisoni*), and, like that variety, it yields a very high proportion of lint, *viz.*, 37 per cent. in ginning.

These varieties have been most carefully tested in regard to their yielding capacities at Lyallpur, some of the varieties having been under test for 5 and 6 years. And some of the tests have been reduplicated upwards of 30 times. The results of these tests have been in most cases remarkably constant, though distinctly different to what was to be expected.

Testing of "desi" varieties.

The best variety as regards heavy yield is undoubtedly *G. indicum, Var. Mollisoni*, and the next best is *G. neglectum, Var roseum*. The tests hardly enable us to place the remainder exactly in order, but apparently none is so good as roseum. Roseum is an important variety over that tract of India which supplies the cotton known to the trade as Bengals and Oomras. Yet the other white-flowered variety appears to be the better yielder in this Province, and the lint is similar and the ginning outturn better. Again these white-flowered varieties yield the kind of cotton most favoured by the local buyers, and are also the heaviest yielders. Yet the yellow and red-flowered varieties are the commoner in most of the cotton growing parts of the Punjab, especially the colonies. No satisfactory explanation of this peculiarity is forthcoming, and it ought to form an interesting and profitable subject of investigation.

Superiority of *Mollisoni* in yields.

In India country cotton from the Punjab is used for spinning, though it will spin only a very coarse thread about 6 to 10 "counts." It is also used for mixing with finer cottons, which, if spun alone, make a thread too weak for weaving in this country. It is very suitable for this purpose on account of its roughness or curl. The country cotton from the Punjab, when exported from India, used to go chiefly to the continent of Europe and to Japan. None went to England. Since the War Japan has been the chief exporter. In Europe this cotton was apparently not used for spinning alone, but was mixed with wool in the manufacture of cheap cloth and blanket, or used for the manufacture of felted goods, padding, etc., and also in the making of guncotton.

Uses of Indian cotton.

The American cotton grown in the Punjab has fibres practically an inch in length. The fibre is fine, but not very strong. This cotton is just about the same as Middling American, and can be used in the Lancashire mills.

The question naturally arises as to whether it is possible to grow longer kinds of American cotton. Most American cottons will grow in the Punjab. But newly imported and superior varieties are less hardy and generally yield less, whilst there is always a fear that they will

Improvement of American cotton.

fail entirely in a bad year. For one thing experience has shown that only varieties having "rough" or hairy leaves will do well in this climate. This seems to be due to the fact that varieties whose leaves are not thus protected are liable to attack by a class of small insect called jassids. It may also be that the "hairs" protect the leaves from excessive evaporation in the hot dry weather of this Province. For some reason, which is not very obvious, in most of the strains and varieties tried here this property of having rough leaves seems usually to be associated with short fibre; and although various strains bearing longer lint have been tested at Lyallpur, none have yet been found to yield consistently equal to the rather short fibred but hardy variety No. 4 F., which has now been extended to a very large area. Since, however, systematic selection and testing is always going on at Lyallpur, and since already more than half the American cotton seed in the Province is purchased direct from the Agricultural Department, there is every reason to hope that the quality and uniformity of the crop will improve, and also that within a few years it may be possible to introduce a variety having lint at least an eighth of an inch longer than that now grown, and thus worth a penny or a penny and a half per pound of lint more. It will be seen, however, that it is essential that any such variety should yield as well as that which we have now. For even one and a half pence more per pound of lint only corresponds to Rs. 2-8 per maund of seed cotton; on average crop of 5 or 6 maunds this amounts to only Rs 12-8 or Rs. 15. Thus, if this superior variety yields on an average only half a maund per acre less than our present strain, there will be no profit in the change with cotton over Rs. 20 per maund of kappas.

Recently, *i.e.* in 1919-20, the premium for staple has been as much as 4 pence for $\frac{1}{8}$th inch difference in staple, and with this and a fall in price of ordinary cotton, the prospects of a variety like 285 F. are very promising even if it yields less than 4 F.

From the foregoing it will be seen that there is little hope of the Punjab growing cottons of anything like $1\frac{1}{2}$ inches length of fibre. But none the less there is every reason to hope that the quality may be improved in time, and that the Province will sell cotton well over an inch in length.

Diseases and pests.

Cotton in the Punjab suffers from several pests, though fortunately the results are seldom disastrous. The most serious pest is the spotted

NOTE.—Cottons are spoken of by the trade as able to spin so many "counts". A "count" is a length of 880 yards or $\frac{1}{2}$ mile of thread. A cotton spinning 6 to 12, such as Punjab "desi" is one from a pound of the lint of which 6 to 12 "counts" can be spun, i. e., 3 to 6 miles of thread. Punjab American 4 F. spins 24 to 32 weft and 16 to 24 twist. No. 285 F. will easily spin 40 weft.

bollworm (*Earias insulana*). This is the caterpillar of a "moth" which lays its eggs on buds, flowers or young bolls The caterpillar bores into the interior, leaving a round hole about $\frac{1}{16}$ inch in diameter, such as might be caused by a small shot. Occasionally, notably in 1905 and 1911, this pest has partially ruined the crop, causing widespread and very serious loss. Fortunately the American cotton seems to suffer much less serious damage from this caterpillar than does the country variety. Even in bad years, such as 1905 and 1911, the American crop was not so badly affected. As the American variety is now rapidly replacing the country cotton in the most important cotton growing districts, there is reason to hope that there will not be a repetition of such serious bollworm damage as in the two disastrous years referred to above.

Bollworm.

There is another insect which kills the bollworm, and it is believed that it is this parasite which keeps the pest in check in ordinary years, and that bad damage from the bollworm only occurs when there is a long interval between its appearance and the appearance of the parasite. The Agricultural Department is experimenting in the direction of importing and artificially breeding and distributing the parasites as early as possible in the season. The experimental work in this direction would appear to justify the hope that this may be a useful safeguard; but it is difficult to prove its actual effect in the field, at all events until a bad "bollworm year" occurs again.

Jassids.

The next most serious pest are the jassids—small leaf sucking bugs. The damage resulting from these is not in the ordinary varieties nearly so serious as that from bollworm. Country cotton and varieties of American cotton having very hairy leaves, though attacked, do not suffer seriously. But the attacks of these insects prevent the growing of any varieties of American cotton of which the leaves are not hairy.

Miscellaneous pests.

Cotton also suffers casual damage, which may be serious in some fields, from a number of other insects. The young plants are often attacked by grasshoppers and cutworms, and occasionally by locusts; weakly plants are sometimes attacked by white ants, but these never damage the crop as they do in the case of wheat; the leaves of bigger plants are attacked to a slight degree by leaf eating caterpillars, but the damage is never of any importance. Much seed is damaged in the opening bolls every year by red and dusky juice sucking bugs, which also stain the lint to some extent. Recently in the newly cleared land of the western part of

the Lower Bari Doab Canal newly germinated cotton has been very badly damaged by a weevil (*Myllocerus blandus*). Probably, however, this is in some way connected with the recent clearing of that area, and it may be hoped that this trouble will cease in a few years. Some good may possibly be done by growing maize with the cotton and destroying the insects that congregate in the maize plants.

Root-rot

There is one other disease the exact nature of which is not known, but which would appear from the symptoms to be due to a fungus in the soil attacking the roots of the plants. This is spoken of cotton root-rot In July and August it kills the crop on very definite limited areas on light soils with a tendency to kallar. On these areas the plants are totally destroyed. As yet the disease can hardly be spoken of as being very serious, for fortunately the patches affected in most fields are not very large, and they do not occur at all in many fields. But there is reason to fear that on light soils this disease may become much more serious as time goes on unless some means of checking it can be found. For root-rot seems to reappear always on the same patch of ground ; but the patches seem to increase in size every time the land is cropped with cotton. A rest from cotton of several years does not seem to prevent its re-occurrence. Various agencies have been suggested as possible causes of this disease, but none is yet definitely proved to be responsible. And various empirical remedies have been tried, but without success.

Hail, etc.

The cotton crop is also very liable to damage from rain or hail at certain stages of its growth. At the sowing time the seed may be prevented from germinating, or very young plants may be killed by rain or hail, as already described. At the time of flowering heavy rain always results in the shedding of a certain number of flowers every day throughout the flowering season ; rain at intervals does not do such serious damage even though it may be very heavy. But a long spell of rainy weather results in a considerable diminution of the yield.

Dry weather.

It is also said that very hot dry weather during the periods of preliminary growth or during the period of flowering lessens the yield. This is certainly true of the Province as a whole in practice, for in such a year many fields cannot receive as much irrigation as they need. Whether it is actually true that some rainy or cloudy weather is necessary for a cotton field to give a maximum yield in this Province, however much irrigation be given, is by no means so certain. In years like 1919 and 1920, when the rains stopped

early and the proportion of cotton sown was high in irrigated tracts, a good deal of damage results through the " bolls " failing to open properly, and a large proportion of immature seed appears in the first pickings. Where the water supply is ample the damage is negligible, though it is undoubtedly fairly serious for the canal areas as a whole. In this respect American cotton being later suffers worse than "desi."

Effect of late rain on germination of seed.

Rain, or worse still hail, late in the season when the bolls are opening naturally damages or destroys the ripe or nearly ripe bolls. It also seems to result in a failure of much of the seed to mature and fill properly, so that in the season following year of late rain it must always be expected that the germination of the seed will be poor. From all these calamities due to the weather, except early cessation of rain, the American cotton enjoys some degree of immunity as compared to the country cotton. This is due to the fact that the season during which the American cotton is producing flowers plentifully lasts much longer than the corresponding season in the case of the country cotton. So that as a spell of bad weather seldom lasts long in this Province, the extent of the damage which it does to American cotton is naturally less than to country cotton.

Frost.

Frost seldom does much damage to Indian cotton, but it always results in the deterioration of the quality of the last pickings of American, and there are usually a certain number of bolls which are killed by the cold without opening at all. It possibly makes a difference of quarter of a maund, perhaps even sometimes half a maund, in the yield of American cotton if the winter is mild and late.

Cost of cultivation and profit from an acre of " desi " cotton.

	Rs.	a.	p.
	per	acre.	
Outlay—			
Two ploughings	3	0	0
Sohagaing	0	8	0
Seed, 4 seers	0	6	0
Sowing (ploughing, sohagaing and sowing) ...	2	0	0
Hoeing by hand	3	0	0
Hoeing with a plough	1	0	0
Picking, a tenth share	6	0	0
Water rate, revenue cesses, etc.	10	0	0
Total ...	25	14	0
Return—			
6 maunds at Rs. 10	60	0	0
Profit	34	2	0

Rent is not included in above. With American cotton the extra profit, assuming equal yield and a premium of Rs. 3 per maund comes to Rs. 18.

CHAPTER XII.—SUGARCANE.

Natural Order—Gramineæ.

Botanical name—*Saccha. am officinarum.*

Area—380,000* acres.

Area.

India is in point of area the chief grower of sugarcane in the world (total area in India rather less than $2\frac{1}{2}$ million acres as a rule), and the Punjab has the second largest area among the provinces, the area here usually varying between $3\frac{1}{2}$ and 4 lakhs of acres. But on the whole India is far below other countries in the matter of yield per acre, and the Punjab is similarly far below the rest of India in this matter.

Yield.

Thus the yield of cane in the Java and the Sandwich Islands is said to be over 30 tons per acre, and the yields of refined sugar about $3\frac{1}{2}$ and 8 tons respectively. In Bombay and Madras the yield of raw sugar per acre is generally estimated at between $2\frac{1}{2}$ and 3 tons per acre. The official estimates for the Punjab are not generally much over $\frac{3}{4}$ of a ton of raw sugar or "gur"; and certainly 1 ton per acre is an average good crop in most parts of this province.

Importance of the crop.

The proportion which sugarcane bears to the total area of crops in the Punjab is usually rather less than $1\frac{1}{2}$ per cent. None the less the crop has an importance greater than that indicated by these figures. For the value of the return per acre is high in comparison to that from most crops in this Province; and, moreover, the amounts of labour, manure, and water which go to the production of an acre of sugarcane are several times greater than the amounts expended in the production of an acre of most other crops.

Varieties.

The bulk of the cane grown in this Province belongs to only two varieties. Most of the cane grown for the production of sugar is of the variety called "katha." Most of the cane grown for chewing consists of the variety called "ponda." "Ponda" is a thick green cane not unlike those grown in other parts of the world. "Katha," on the other hand, is a thin fibrous cane, not more than half

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* For the quinquennium ending 1916-17 "Agricultural Statistics, India."

an inch thick and having rather long internodes. Such a cane is hardly to be seen outside the Punjab. In one or two favoured districts, where the climate is more suited to the growth of cane, thicker canes, such as those called "kansar," "dhaulu," and "kahu," are grown for the extraction of sugar; but in most parts the "katha" is chiefly used for this purpose. For to grow a thick cane in this Province and get a fair crop of cane, the soil needs a great deal of manuring, watering and cultivation. When this is done a good crop of cane can be grown; but in many years it will not yield a solid raw sugar. This is apparently due to the fact that such a crop will not ripen properly on account of the early cold weather and mainly to the fact that growth is not active in the early hot summer months.

Distribution.

The best areas for the growth of this crop are in the south-east of the province in the districts of Rohtak and Karnal. Next after these come the eastern districts such as Gurdaspur and Sialkot. It is only in such parts that any thicker varieties than "katha" are grown for the extraction of sugar.

Suitable soils.

The rainfall in the Punjab plains is nowhere sufficient for the growth of sugarcane; and thus this crop can only be grown either under irrigation or where, as in the beds of rivers, the underground water replaces irrigation. It can only be grown profitably on land which is at least moderately heavy; it is useless to try to grow sugarcane on the lightest soils.

Seasons.

The sugarcane crop is planted in March in this Province, and it is harvested in the winter from December to February or early March. The crop thus actually occupies the land for almost exactly a year; but for practical purposes it must be regarded as occupying the land for upwards of fifteen months. For the soil must be particularly thoroughly prepared for cane, and moreover after the cane is harvested the soil seems to be left in very poor tilth and encumbered by the stumps. Thus more time and labour is required to prepare sugarcane land for, say cotton, than to prepare the stubbles of wheat, "toria," or "senji" equally well.

Rotation.

Sugarcane cannot follow the ordinary winter crops—wheat and gram; it must either follow "senji," "toria," or a fallow. So far as the dates are concerned, it could follow cotton, but actually cane is not

often sown after cotton ; on irrigated land sugarcane most often follows "senji," sown between the ripening plants of the maize crop. In the river beds, and more rarely on wells, the crop is sometimes sown after a long fallow ; but this rotation—maize, senji, cane—is commonest, wherever cane is grown, all over the Province. There is more variation in the matter of the crop following the cane, as this may be wheat or cotton according to district or other circumstances.

Manuring.

Sugarcane must be sown on manured land. The amount of manure applied is usually from 20 to 30 cartloads per acre (say 15 to 20 tons) in the case of thin cane, and even more where "ponda" is grown. This manure is, however, rarely applied directly to the land before planting the cane. One reason for this is said to be the fact that freshly applied manure attracts white ants which damage the cane. An even more important reason is probably that directly applied manure delays the ripening of the cane.

The greater part, or more commonly all, of this manure is therefore applied to the maize crop. The residue of the "senji" crop probably adds still further to the amount of nitrogen in the soil before the cane is sown. In spite of all this the sugarcane crop is regarded as an exhaustive one, leaving the soil temporarily poor. When any farmyard manure is added directly to the land under preparation for cane, it is added in the winter some months before the planting time. Only in the case of the thick cane grown for chewing is a little very well rotted manure sometimes added as a top dressing to the young crop.

Cultivation.

As said above sugarcane here usually follows "senji." The "senji" is usually cut in February, so that nearly a month is left for preparing the soil for the cane. During this time the land is most thoroughly cultivated. Where only country implements are used, the land is ploughed six or more times and treated several times with the "sohaga." The seed-bed prepared for sugarcane is much deeper and finer than for any other crop excepting potatoes. It is possible that the condition of the seed-bed is of special importance in the case of these crops which are vegetatively reproduced.

Propagation.

The "seed" of sugarcane consists of short sections of the cane including two "nodes" or joints and buds. In the case of the thin cane of this Province, the sets are thus about a foot long. The treatment of the canes to be used for sets varies considerably. In some

parts they are allowed to stand in the field until required; elsewhere whole canes are buried in the ground early in the season until needed; and in other places the upper parts of the cane are taken out every day when the crop is being cut, and these are buried for use as sets. Such sets from the tops of the cane give a very good plant, and the practice is economical, for the upper part of the cane contains less sugar than the lower. It is said, however, that the crops from such sets ripen later. The object of burying the canes for sets, where this is done, is to protect the buds on them from frost. In the case of the thin Punjab canes the area of crop needed to provide sets is one-fortieth of the area to be sown.

For sowing the land is irrigated, and then ploughed and levelled once or twice. It is of the greatest importance that the land should be in exactly the right state of moistness at the time of sowing. The crop will suffer if it is sown in soil that is either too moist or too dry. The sets are placed by hand in furrows made about a foot apart by means of a country plough, the sets being placed about 6 or 9 inches apart in the rows.

Hoeing hoed and weeding.

The sugarcane crop is hoed very frequently. The hoeing often starts before the crop is visible at all or the land has been irrigated. It is subsequently hoed after each irrigation. The total number of hoeings amount to as many as six or seven, and is never less than three. These hoeings are done with a special implement called "baguri"; the last hoeing; however, is particularly deep, and is done with a "kahi" or "kasola."

Watering.

The crop will stand without irrigation for a couple of weeks before the first watering, but after this it needs to be irrigated very frequently. During the months of April, May and June, and early July, waterings have to be given about every ten days on most soils. After this the waterings do not seem to need to be quite so frequent; but if no rain occurs waterings may be needed at intervals of 14, and later of twenty, days or so. Thus in the absence of rain the total number of irrigations given to a field of thin cane will amount to nearly twenty. But normally the rain replaces some of this. The actual depth of each watering to cane is probably not very great, as the soil is never allowed to dry out. The total quantity of water given is thus probably commonly from 50 to 60 inches.

Where thick cane is grown the watering is even heavier and may possibly amount to as much as 80 inches.

As already stated, the cutting of the crop starts about the beginning of December or even at the end of November. The cutting and stripping of the cane is generally done by casual labour, which is recompensed by the value for fodder of the tops and upper leaves which the cutters are allowed to take away.

Harvest.

The crushing and boiling is carried out by the farmers themselves, and it occupies most of their time as a rule during these two months of December and January. The mills used are small iron ones with vertical rollers, made in the Province. The old horizontal wooden mill is now only to be seen very rarely. The best mills are the three-roller mills which are let out on hire by the Nahan foundry; but the ones most commonly seen are the two or three-roller Batala mills The pre-war prices of these three types of mills were as follows :—

Crushing and boiling.

	Rs.
Nahan Sultan mill	120
Present price	236
Batala 2-roller mill	35
Present price	55

An additional roller can be had for Rs. 10.

A new type is now being produced at Batala in Gurdáspur *District on the lines of the Nahan mill. The cost is* Rs. 140.

The juice after extraction is boiled down in a small shallow pan about 4½ feet diameter and costing now Rs. 50. It will hold three earthen 'muts' or kerosine tins full of juice, each having about 21 seers. A boiling contains therefore about 62 to 63 seers. From 12 to 16 boilings a day of 24 hours can be done with one furnace and a mill of the Nahan type. Three men are required to do the crushing and boiling. During boiling the scum which collects on the surface is periodically removed with a long handled sieve. In Jullundur and Hoshiarpur the people often use the extract of the bark of a plant called "suklai" (*Kydia calycina, Rox.*) for clarifying the juice. A better coloured "gur" is obtained in this way. In Gurdaspur, if the season has been wet and the cane not properly ripe, lime is often used for clarifying. When four-fifths of the juice is evaporated the contents are poured into another vessel and allowed to cool. "Gur" in the Punjab is put on the market in lumps of *about a seer weight.*

"Gur" manufacture.

"Ráb." When white sugar is required, the juice is not boiled so far as in making "gur." The liquid thus obtained is known as "ráb."

"Shakkar." For making "shakkar" the juice is boiled longer than when making "gur," and a loss of 5 per cent. or so results. After cooling the mass is broken up into small pieces or granulated and sold as a powder.

Generally a hundred maunds of this cane after stripping will give 55 maunds of juice with the Nahan mill, and this will yield 10 or 11 maunds of "gur." A good average yield is said to be 30 maunds of "gur." Yields up to 80 maunds per acre have been obtained at Lyallpur with "suretha" cane.

Varieties. A large number of varieties are being tested at the Gurdaspur Station. At Lyallpur a variety called "suretha" is showing promise.

Produce of sugar per acre. The possibility of increasing or improving the yield from sugarcane in this part of India has frequently been discussed, but it is a subject about which there seems to be a great deal of misconception.

It is said that the yield of sugar from an acre of cane in this country is low for three reasons :—

(1) The actual amount of sugar produced in the crop on an acre of cane is very low.

(2) An unnecessarily large amount of this sugar is lost through imperfect extraction of the juice.

(3) That there are great losses of cane sugar through inversion to glucose.

If each of the points is carefully considered, the prospects of radical improvement are not very promising. The climate in most parts of the province seems to prevent good varieties of cane from ripening properly every year. Some improvement in this respect may be possible, but it must be remembered that the amount of water, manure, and cultivation which must be given to cane tell seriously against it in competition with other crops, especially cotton, for which the climate of most parts of the Punjab is more suitable.

Expression of juice. Large factories in the United Provinces using batteries of nine or more rollers driven by steam or oil engines extract juice to as high an amount as 66 per cent. of the weight of cane; but even their canes are probably thicker than those in the Punjab. The ordinary three-roller mill in the Punjab will always

express 50 per cent., and with the Nahan mill properly set the expression in most years should average over this figure even for thin canes. It is therefore probable that this ratio can be increased by at least 10 per cent. by using such a battery of rollers, which would mean an increase of 20 per cent. more juice. Thus there is at least some possibility of such a mill being successful, if the engine could be used for other purposes at other times of the year. But even so the prospects for success are not very bright except where sugarcane occupies a fairly large proportion of the cropped area and transport is easy.

Comparison of sugar and "gur" prices.

A comparison has been made of the prices of sugar and "gur" at Lahore. The sugar prices have been calculated from the price of white sugar (dearest) prevailing in the end of January at Bombay as supplied by the Director of Statistics, including the railway freight (about Rs. 1-4-0), correct to nearest one-fourth of a rupee. The prices of "gur" are those prevailing at harvest time as given in the "Season and Crop Reports," Punjab.

Year.	Wholesale price of sugar per maund at Lahore (including Ry. freight). Rs. a. p.	Price of "gur" per maund at Lahore. Rs. a. p.
1910	10 4 0	5 0 0
1911	8 12 0	4 2 0
1912	11 4 0	5 8 0
1913	9 2 0	4 15 0
1914	8 4 0	4 11 0
1915	13 12 0	5 5 0
1916	14 12 0	5 0 0
1917	16 4 0	5 0 0
1918	14 12 0	6 0 0
1919	16 4 0	9 2 0
1920	29 12 0	11 8 0
1921 (January)	24 0 0	8 0 0

From the figures published from the Nawab Ganj Factory* (United Provinces) it appears that it will not pay to make white sugar until the price of white sugar is distinctly more than double the price of "gur," assuming the price of molasses to be equal to the extra cost of sugar-making.

The price which Hulme got for his molasses was Rs. 2,948, and the price of fuel purchased was Rs. 4,264.

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* NOTE.—Nawabganj Factory 1917-18—

Maunds.

36,700 maunds cane gave { 2,075 sugar, 1,430 molasses.

$\frac{\text{Juice}}{\text{Cane}}$	...	66 per cent. (average).
$\frac{\text{Sugar}}{\text{Cane}}$	...	5·7 ,,
$\frac{\text{Molasses}}{\text{Cane}}$	..	3·9 ,,
$\frac{\text{Sugar}}{\text{Juice}}$	...	8·5 ,,
$\frac{\text{Molasses}}{\text{Juice}}$	..	6 ,,

Hulme estimates with small well equipped factory working thin canes.
- $\frac{\text{Juice}}{\text{Cane}}$ normally 66 per cent.
- $\frac{\text{Sugar}}{\text{Cane}}$ could be 6 ,,
- $\frac{\text{Gur}}{\text{Cane}}$ should be 12 ,,

Cost of cultivation and yield of "gur" from an acre of sugarcane crop.

	Rs.	a.	p.
Outlay—			
Six ploughings at Re. 1-8-0	9	0	0
Farmyard manure (residue from maize) ..	18	0	0
Seed—8 marlas at Re. 1-12-0	14	0	0
Preparation of seed	2	0	0
Seed-bed preparation	2	0	0
Sowing	4	0	0
Three hoeings	18	0	0
Labour charges for 12 waterings	3	0	0
Land revenue and water rate, etc.	15	0	0
Cane crushing	32	0	0
Furnace feeder (fireman)	7	0	0
"Gur" maker	7	0	0
Hiring of machine	5	0	0
Total ...	136	0	0
Return—			
Yield of 25 maunds of "gur" at Rs. 8 per maund ...	200	0	0
Profit	64	0	0
	per acre excluding rent		

CHAPTER XIII.—MAIZE, "JUAR" AND "BAJRA."

Distribution.

These three crops fulfil similar functions in different districts, and are hence grouped together. Maize is grown where rainfall or irrigation is plentiful; "bajra" in the dry parts of the Ambala and Rawalpindi Divisions, where it is a very important crop; "juar" occupies an intermediate position, being less drought resistant than "bajra," but much more so than maize. All three can be grown either for grain or fodder; in the latter case they are sown more thickly, though in dry years crops grown for grain are often used as fodder. Maize is mostly grown in the submontane districts, its chief centre being Jullundur. In the canal colonies maize is chiefly grown for grain, whereas "juar" is almost exclusively grown for fodder ("chari"), and generally now a days as a mixture with "guara." "Bajra" is rarely grown in the colonies.

Areas.

The area under maize, depending, as it does, on irrigation and safe rainfall conditions, does not vary much from year to year. The area of "juar" and "bajra" fluctuates enormously, *e.g.*, the total area of these two was 30 lakhs of acres in 1915 and 45 lakhs in 1916.

MAIZE (VERNACULAR "MAKKI").

Natural Order—Gramineæ.

Botanical name—*Zea mays.*

Area—1,200,000 acres.

Area.

The area of maize grown in this Province is usually between 10 and 12 lakhs of acres or about 4 per cent. of the total area of all crops in the Province. Of this area about 4 lakhs or so usually is irrigated, which represents about 4 per cent. of the total area of all irrigated crops.

Distribution.

Like sugarcane, however, maize is more important than these figures would appear to indicate; for it is only grown in certain limited parts of the Province. It is a popular and profitable crop wherever it can be grown without irrigation. Excepting in some river bed lands, this is only possible where the monsoon is fairly early and very reliable. Thus in such districts as Kangra, Hoshiarpur, and Ambala considerable areas of maize are grown without irrigation or manure. In such circumstances the crop is profitable even if the yield per acre is not much more than ten maunds per acre. But if the maize has to be irrigated, then it is only grown where the water is obtained fairly cheaply and where the standard of farming is high. Thus maize is regularly grown on small areas in Jullundur and Lyallpur, where the yield is commonly upwards of 20 maunds. Outside such areas maize is of little importance. In many districts the crop is hardly to be seen at all. The total average outturn of maize in the Province may be estimated at about half a million tons.

Soils suitable.

Maize is essentially a crop of the better classes of loams. It is never grown on the more sandy soils.

Time of sowing.

The time for sowing maize varies a great deal. It is ordinarily late June or early July; but it is sometimes sown as early as May in the hills or as late as August in the Lyallpur district. The harvest period varies from September to November according to the time of sowing.

Common rotations.

In the plains maize is commonly rotated with sugarcane, cotton or wheat. It is only followed by wheat where it is sown early, and hence very rarely in the colonies. The rabi crops which are most often sown after maize are "senji" on irrigated land and "massar" (*lentils*) on unirrigated lands. The next kharif crop may be either cotton

or sugarcane In the hills and some sub-montane places maize is rotated with potatoes.

The soil is usually rather thoroughly prep red for maize by several ploughings.

Manuring.

As has already been said, maize on irrigated lands is almost invariably manured; and if sugarcane is to follow, it is often manured, as much as 32 cartloads or about 25 tons being sometimes applied, though it is more commonly about 25 cartloads per acre.

Method of sowing and after cultivation.

In those wetter districts where maize is grown without irrigation it is generally sown broadcast. On the irrigated lands in drier parts it is often sown by dropping the seed in the furrows behind the country plough. It can be sown by the same drills as those *recommended for the sowing of country cotton. Maize* receives at least one after-cultivation, and if sown in lines may be intercultured 3 or 4 times. When grown for fodder, as is sometimes done, it should be broadcasted.

Seed-rate.

The seed-rate is usually about 6 seers (12 pounds), though local practices vary to some extent in this respect. If sown for fodder, the seed-rate should be not less than 12 seers.

Watering.

In the absence of rain maize may need irrigation as frequently as every ten days during the six weeks of the most rapid growth. Naturally less frequent *irrigation is needed for the very young crop, and* also when it is almost ripe.

Unirrigated maize is generally also unmanured, and the yield of a fairly good field under such circumstances may be taken as about 10 or 12 maunds per acre. When irrigated and manured the yield of an average good crop is about twice as much, or about 24 maunds per acre, although when heavily manured and amply watered, and when all conditions are favourable, yields of 40 maunds of maize per acre are obtained. The average yield in the Punjab, as judged from the statistics of crop returns, is about 10 or 11 maunds as against about 9 maunds for the whole of India and about 20 for the United States of America.

Competition of maize with cotton and "juar."

The crops with which maize chiefly competes are cotton and "chari." Although both crops are manured, yet sugarcane and maize do not compete to any great extent. For sugarcane is not generally manured directly, but is grown on land which has recently been manured for some other crop. For this purpose maize is particularly

suitable, and the growing of maize and sugarcane are generally associated. Moreover, if the area of sugarcane is limited at all by the water supply, it is by the water supply during the months from May to July rather than by the later months when maize is grown.

Where cotton does not do well, then maize is the most profitable kharif crop wherever the land is good enough and the water supply regular enough for it to grow. Where cotton yields well, maize will have to be irrigated. In such places at normal prices, there is little difference in the profit from these two crops; though cotton is perhaps rather the more profitable, but both may well be grown on the same farm. At the prices which have held lately, cotton is much more profitable, and the area of maize is tending to decrease in such districts as Lyallpur, where these two crops compete. It is, however, unlikely that it will be given up entirely, for the farmer is wisely loth to reduce the number of his crops too far, and, as has already been said, maize is a particularly suitable crop to precede sugarcane.

Varieties of maize.

The only different kinds of maize definitely recognized by Punjab farmers are red and white; but there are great differences between various plants in any field, and there is little doubt that the crop could be greatly improved by seed selection.

Maize for fodder.

Maize is to some extent used for fodder. In this respect it is especially useful for sowing in the early part of the kharif season, as at this time of the year it grows quicker than "chari". It is thus sown in late March or April usually mixed with "sawank" and "moth." For this purpose it is sown broadcast. Later in the season it is sometimes mixed with "chari."

Pests.

The only serious pest which does appreciable damage to the crop is maize-borer. In some years the insect is very destructive to the young crop After maize is harvested in November, the insect hibernates in the stubble as a caterpillar, and can easily be destroyed then. Such land must always be ploughed before the end of March and stubble collected and burnt.

"JUAR" OR "CHARI" (GREAT MILLET).

Natural Order—Gramineæ.
Botanical name—*Andropogon sorghum.*
Area—1,250,000 acres.

Distribution.

This is extensively grown in Bombay, Madras, United Provinces, Central Province, and the Punjab. Both a kharif and rabi type are grown in Western India. In the Punjab, only kharif "juar" is known. The crop is mainly "barani" in the Punjab though it is grown extensively for fodder in the colonies generally mixed with "guara."

Seed-rate.

For grain 8 to 10 seers and for fodder 24 seers per acre are generally sown.

Cultivation.

From two to four ploughings are given as a rule. The cultivation is not as thorough as for maize. It is generally sown broadcast. It is often mixed with "guara," "moth," "mash," "mung," "lobia" (*Vigna catiang*) or "til." The common rotations are :—

(1) Cotton, "Juar."
(2) Wheat, "Juar."
(3) Cotton, "Juar," "Sann" (ploughed in), and wheat.
(4) Gram, "Juar."

The food value of "juar" grain may be seen from the following table :—

	Proteins.	Starch.	Oil or fat.
	Per cent.	Per cent.	Per cent.
"Juar"	9·3	72·3	2
Rice	7·3	78·3	·6
Wheat	13·6	68·4	1·2
Oats	10·1	56	2·3

"Juar" fodder and turnips compare as follows :—

	Green "juar."	Turnips.
Water	85·17	90·43
Protein	2·55	1·04
Starch and fat	11·14	7·89
Ash	1·14	·64

"Juar" stalks too, even when the grain has been taken off, are valuable as fodder and eaten readily by cattle. In the case of maize grown for grain, the stalks are rarely used for cattle food "Juar" stalks can be stacked and stored as "karbi" for several years. It may be sown for early fodder at the end of March or April and, for grain from June to July or early August. The crop sown for fodder is ready in 10 to 12 weeks.

Yield.

The yield for grain is from 10 to 14 maunds per acre, and of green fodder averages 280 maunds or ten tons.

Diseases.

The grain is sometimes extensively damaged by *smut* or *bunt* as in the case of oats. Treatment of seed with copper sulphate solution of ½ per cent. strength is effective in preventing appearance of *smut.* Sometimes with untimely rains seed forming is affected in the Punjab, and seed for the following season is expensive and difficult to secure except by importing in large quantities from Central India.

Varieties.

Two or three types are generally recognized by zemindars depending on the taste and colour of the seed. Actually a very large number of varieties are found in the crops generally grown, and much useful work remains to be done in the selection and testing of these.

"BAJRA" (BULRUSH OR SPIKED MILLET).

Natural Order—Gramineæ.

Botanical name—*Pennisetum typhoideum.*

Area—2,600,000 acres.

This crop is the hardiest of the kharif fodders, and is grown mostly in the dry parts of the Ambala and Rawalpindi Divisions. It is practically all "barani." It will grow on poor sandy soil, whereas "juar" requires a stiffer loam, and maize only does well on good stiff loam. The area of "bajra" fluctuates enormously, being as high as 30 lakhs in a good year and less than 20 lakhs in a year of poor rainfall.

"Bajra" has a shorter growing season than "juar" or maize, and can thus be sown later than these crops. Most of the crop is sown in early August, though if the rains are timely it can be sown at the end of June. It is very rarely irrigated.

The cultivation is similar to that of "juar." The grain is used largely for human consumption among the poorer classes, especially in the tracts where the crop is grown. The stalks are valued as fodder. No selection work has yet been done in this crop, though it is of very great importance in the north and extreme south of the Province, where it constitutes often three-quarters of the total kharif area.

CHAPTER XIV.—PULSES.

GRAM.

Natural Order—Leguminosæ
Botanical name—*Cicer arietinum.*
Vernacular name—"Channa."
Area—4,000,000 acres.

Gram is a leguminous rabi crop. It is probably indigenous in South-Eastern Europe or South-Western Asia. Its cultivation in India is ancient, as its Sanskrit name "Chanaka" indicates. The Romans called it "Cicer". It is called "arietinum" from the resemblance of the seed when forming in the pod to the head of a ram.

Distribution general.

Gram is an important crop in the upper basins of the Ganges and the Indus. The tract north of a line from Bombay to Patna constitutes the gram producing areas, its chief centre being the Province of Agra.

Punjab.

The area grown in the Punjab is about 4 million acres, of which only about 12 per cent. is irrigated. The largest areas are found in Ferozepore, Hissar, and Rohtak.

Gram is the earliest sown of the rabi crops. It is sown from the middle of September to the middle of October.

It is generally sown on land which lay fallow in the *kharif*, but is also often grown after early fodder crops, such as "juar" and "guara." It is often sown mixed with wheat, linseed, "taramira," "sarson," barley or peas. Gram is sown on all soils from the heaviest clay loams to the lightest sandy loam; but it is on the former class of soil that it yields best, and is generally grown alone in such cases. This crop grows better than any others on the lightest soils of the Province, and is often in such cases grown mixed with wheat or with barley. Should winter rains be favourable, the wheat or barley gives a good yield, whereas the gram subsists best when rains fail. The seed bed is generally roughly prepared, but a deep tilth is favourable, though the soil need not be pulverized as in case of wheat.

Seed-rate and sowing.

The seed-rate in the Punjab is generally from 12 to 15 seers as compared to 40 or 50 seers in the Central Provinces. It is generally sown behind the plough. In "sailaba" land it is often sown broadcast without any previous cultivation, and merely covered by ploughing once or twice. In irrigated land one or

at most two waterings after sowing are given. The crop is rarely weeded, but sheep and goats are sometimes allowed to nip off the top shoots just before flowering in order to encourage branching. Rains after early February, if heavy, are apt to damage the crop, especially if it is in flower. It ripens a fortnight or three weeks before wheat. After cutting by the "*daranti*" it is left to dry for 3 or 4 days, and then threshed as in case of wheat.

The yield is less than that of wheat on similar land under good conditions. It ranges from 8 to 20 maunds or more per acre.

Gram, being deep rooted, is injured by application of irrigation during the early stages of growth. It is damaged by white ants to some extent, and suffers also from a caterpillar known as "sundi" or "bahaduri." Frost does considerable damage in some years, mostly at end of January and early February.

Uses.

(1) The green shoots and pods are eaten raw or cooked.

(2) The ripe grain is eaten cooked as "dal" or in parched form.

(3) When crushed into flour the latter is used in the preparation of biscuits and sweetmeats.

(4) It is used extensively for feeding horses and cattle, and is an excellent concentrated food. Recently its use in Europe for these purposes has extended, and the price now tends to equal or even sometimes exceed that of wheat.

(5) The chaff as "missa bhusa" is relished by stock.

Cost of cultivation.

	Rs.	a.	p.
Outlay—			
Ploughings, 2 at Re. 1-8-0	3	0	0
Seed, 15 seers, at Rs. 5 per maund ..	1	12	0
Sowing	1	0	0
Reaping (4 men per acre)	5	0	0
Threshing (one pair and 2 men)	3	8	0
Winnowing and cleaning (2 seers per maund) ...	3	8	0
Watering rate	2	8	0
Land revenue	4	0	0
Local cess	0	11	0
Total ...	24	15	0
Return--			
Yield, 12 maunds, at Rs. 4 per maund ..	48	0	0
Bhusa, 16 maunds, at Re. 1 per maund ...	16	0	0
	64	0	0
Profit per acre (not deducting rent) ..	39	1	0

The crop as generally grown by zemindars consists of a number of varieties. These are being now separated and tested at Lyallpur. Some of the varieties appear to yield much more than the usual mixture grown. Five types only are generally recognized by zemindars, *viz.*, the small and large kabuli, and the black, brown or yellow seeded local variety.

The preservation of a loose open soil is important for this crop, and harrowing in the early stages of growth by means of the Bar harrow is beneficial. Gram being a leguminous deep-rooted crop tends to improve the soil, and adds nitrogen to it.

MASSAR (*LENTIL*).

Natural Order—Leguminosæ.

Botanical name—*Lens esculenta*.

Area—160,000 acres in 1890 (later figures not available). 25,000 acres were irrigated by canals in 1918-19.*

This is a small pulse crop grown to a limited extent all over the Province. It is frequently grown on "sailaba" land, and is generally the first crop sown on new alluvial soils recovered from the rivers, and also sometimes follows "mattar" (field peas) on such soils. It is generally sown alone, but is sometimes sown mixed with barley in Hoshiarpur District. It is rarely sown on land which has been fallow the previous kharif, and hence it is a suitable crop to follow "juar," rice, etc.

The cultivation given is meagre, and consists of one or two ploughings only. It is sown broadcast at the rate of 12 to 16 seers in October or November. It can be sown very late, sometimes even in January. The average yield is about 6 maunds grain and 12 maunds "bhusa." It is subject to the same diseases and pests as gram.

Uses.

It is used as a "dal" like "mash" and "mung," and is said to be the most nutritious of the pulses. When taken freely it is heating, and is said to produce skin eruptions. The young green pod, as in the case of gram, is used as a vegetable.

* Administration Report, Punjab Irrigation, 1918-19.

MASH, MUNG, AND MOTH.

These three crops of leguminous kharif pulses fulfil similar function, and are hence grouped together. "Mash" requires stiff loamy soil and a good water-supply; "mung" does best on medium soil, and is more drought resistant; "moth" is grown generally on light sandy soils, and under drier conditions than either of the former. The relation between these three is similar to that between maize, "juar" and "bajra."

MASH.

Natural Order —Leguminosæ.

Botanical name—*Phaseolus radiatus.*

Area under both "mung" and "mash" is 500,000 acres.

The area of "mash" grown does not fluctuate very widely. It is mostly grown as a subordinate crop with maize. It is sown at the end of June or early July when rains have started, and is harvested in October or November. The preparatory tillage when it is grown alone is meagre—two or three ploughings only, and no interculture or weeding is generally done. When grown by itself it is generally a rain crop ("barani"). The yield averages about 8 maunds with 20 maunds "bhusa." The pulse is much valued as human food, and forms part of the daily ration of a great part of the people. The crop is fairly important in the districts of Rawalpindi, Gurdaspur and Hissar.

MUNG.

Natural Order—Leguminosæ.

Botanical name—*Phaseolus mungo.*

Area—(See under "Mash")

The cultivation for the crop is similar to that of "mash." There are two types commonly recognized, *viz.*, the black seeded, found chiefly in Sialkot and Gurdaspur, and the green seeded or common variety.

"Mung" is rarely sown alone, but is commonly sown as a subordinate crop with maize, "juar," and sometimes "bajra." Soils suitable for "juar" suit "mung." The seed-rate when sown alone is 5 seers. The yield is about 10 maunds grain and 20 maunds "bhusa." Heavy or untimely rain, especially at flowering time, damages the crop.

MOTH.

Natural Order—Leguminosæ.

Botanical name—*Phaseolus aconitifolius.*

This is frequently grown for fodder mixed with "juar" or "bajra." The seed rate is 8 seers when it is sown alone. The yield is generally about 8 maunds grain and 15 maunds "bhusa." In canal or irrigated tracts it is often grown mixed with early fodders and also with cotton. It is removed from the latter crop in about August and used as green fodder. It is the most drought resistant of the three kharif pulses discussed above.

CHAPTER XV.—OILSEEDS.

TORIA, SARSON, TARAMIRA, AND RAI.

Natural Order—Cruciferæ.

To this order belong also cabbages, cauliflowers, turnips, etc. In the Punjab as field crops " toria " and " sarson " only are important, though " taramira " (*Eruca sativa*) is grown fairly extensively in dry tracts. " Rai " (*Brassica juncea*) is only rarely grown in the Punjab. " Sarson" (*Brassica campestris, Var. glauca*) and " toria " (*Brassica campestris, Var. toria*) differ considerably as regards their habit and methods of cultivation. " Sarson " is generally grown mixed with gram, barley or wheat, and rarely grown alone. It is mostly grown " barani," and sown along with the other crop in the mixture generally from October to November. It is used largely as fodder or as a vegetable (" ság "). " Toria," on the other hand, is almost invariably grown alone and with irrigation. It is an important crop in the canal colonies. It is sown early in September, or even sometimes at the end of August, and is hence a " zaid kharif crop." It ripens in January, whereas " sarson " ripens in March.

TORIA.

The area under " toria " varies somewhat, but generally reaches about 400,000 acres, of which over a third is grown on the Lower Chenab Canal.

Cultivation of " toria."

The seed (2 to 2½ seers per acre) is generally broadcasted on a moist seed-bed and covered by light tillage with a " desi " plough followed by a light " sohaga." Sometimes the seed is sown on a ploughed seed bed and covered by running the " sohaga " over afterwards. It is very difficult to get even germination in this crop, and patches of bare soil are frequent. It requires two or three waterings, generally only two after sowing. Sometimes in the colonies " toria " is grown mixed with gram, and being off the ground in January enables the latter to flourish alone during the later months of its growth. This mixture is only possible when the " toria " is sown somewhat late, and is not common. The first irrigation after sowing, which is generally given at the end of October or early November, is not favourable

for the development of gram. The average outturn of "toria" is about 8 maunds.

Pests.

The crop is peculiarly liable to the attack of aphis, which, in damp seasons attacks flowers and shoots and causes extensive damage.

The seed is either exported or the oil extracted locally. The cake is valued as a cattle food. The oil is used for cooking in India, and in Europe finds a variety of uses, one of which is as a substitute for olive oil.

"Toria" is very rarely grown for fodder purposes, whereas "sarson" is much valued in this respect. In harvesting generally the upper part of the plant only is cut, thus leaving a good deal of organic matter for ploughing into the soil. Cotton does well after "toria."

"SARSON" (*RAPE*), "TARAMIRA," AND "RAI" (*MUSTARD*).

The returns of area do not distinguish between these, all being returned as rape. The area fluctuates between 400,000 and 900,000 acres,* of which about 14 per cent. only is irrigated. These being generally grown in mixtures get the same cultivation as the crop with which they are sown.

Selective work on "toria."

There are a very large number of varieties of "toria" now being studied at Lyallpur. These differ in every conceivable respect, and as much crossing takes place, their testing and valuation has taken longer than expected. Some promising types are now being grown on a moderately large scale. It is hoped that this work will ultimately result in types being separated suitable for a variety of conditions for which the present crop is not adapted.

The Brassica family owing to their having pods are often thought to be able to fix nitrogen like legumninous crops, but this is not the case

* Season and Crops Report, Punjab.

SESAMUM OR GINGELLY.

Natural Order—Pedalineæ.

Botanical name—*Sesamum indicum.*

Vernacular name—" Til."

Area—130,000 acres *

History. It grows wild in Java and Central Asia. It is supposed to be introduced to India from Africa before the Aryan invasion. It is grown all over India either pure or mixed with other crops.

General characters. Sesamum is an annual herbaceous plant growing to about 4 feet high. The stems are generally erect, but branch freely if thinly sown. The fruit consists of a four-celled capsule of oblong shape, which opens at the top when ripe. The seed is smaller than that of linseed, and is flat in shape, and may be either whitish or dark.

Sesamum in the Punjab is a kharif crop only, and is sown in June or July, and harvested in October or November. It grows best on light soil. The largest area is found in Gurdaspur, but it is important also in Multan and Kangra districts, and to a limited extent all over the Province.

Cultivation and yield. It receives two or three rough ploughings, and 8 to 10 seers of seed are sown per acre. It is often grown mixed with cotton in alternate rows or in parallel lines across the field. It is also sometimes mixed with maize or "kangni," or on the borders of fields growing kharif fodders. The yield when grown alone is about 5 maunds.

Uses The oil extracted from the seed is valuable for human consumption. The seed is partly exported, the white variety "tili" being preferred, as it yields more oil than the black type. The white variety ripens somewhat ealier than the black. (For further particulars regarding uses see Mollison's Indian Agriculture and Watt's Dictionary of Economic Products).

Harvesting. The crop is cut by a sickle. If not dead ripe, it can be carried straight to the threshing floor and stacked upright. If some of the pods are ripe, the plants should be shaken over a cloth carried just behind the harvester, when seed from the capsules that are ripe will drop on the cloth. After drying for 10 days on the threshing floor most of the capsules open, and the seed will fall out if the plants are held top downwards and shaken. This may have to be repeated if all the capsules are not open. The seed is cleaned by winnowing with the "chhaj."

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* For the quinquennium ending 1919-20. "Season and Crops Report," Punjab

The crop is a delicate one and is injured by heavy rain, especially during flowering. It is thus mainly grown in thinly populated tracts where an extensive system of agriculture is practised. It is very little grown in the canal colonies.

The following analysis by Dr. Leather shows the composition of "black and white til" from Poona :—

	White seed.	Black seed.
Moisture	4·87	5·42
Oil	48·13	46·50
Proteins	22·50	25·81
Soluble carbohydrates	14·05	9·06
Woody fibre	4·49	6·52
Ash	5·96	6·69
	100	100
Nitrogen	3·6 per cent.	4·13 per cent.

Til cake is valued as a concentrated cattle food.

Analysis of Til cake.	*(Average.)*
Moisture	10·23
Oil	12·51
Proteins	30·56
Soluble carbohydrates	29·75
Woody fibre	[illegible]·09
Soluble mineral matter	7·14
Sand and silica	2·71
	99·99
Total nitrogen ...	5·93 per cent

SAFFLOWER.

Natural Order—Compositæ.

Botanical name—*Carthamus tinctorius.*

Vernacular name—Kusumbha or Kusum.

Canal irrigated area—300 acres, average for 3 years 1914-15 to 1916-17.

This is not returned separately in crop returns, but is grown in a good many districts, particularly Gujrat, mainly

as a mixture with gram or wheat. It is sometimes grown mixed with cotton also and with other crops.

It is sown in October and flowers in the beginning of March, the seed ripening in April. The plant used to be grown for the sake of the dyes in the flower, and also in some parts of *India as an oilseed. In the Punjab it is mainly grown as a* fodder. Its cultivation is the same as that of the crop with which it is grown If grown for seed, the flowers can be picked and the dye extracted from them without seriously affecting the yield of seed. as fertilization is over before the petals are picked. The yellow dye is extracted by washing in water, but the red colouring matter is extracted with alkali. Cheap aniline dyes prepared from coal-tar have practically killed this industry, though owing to its association with the marriage ceremony the dye is extracted and used locally on a small scale in many parts of India.

The crop when grown with gram and wheat is often removed in January and February and used as fodder.

CHAPTER XVI.—MISCELLANEOUS AND FODDERS

GUARA

Natural Order—Leguminosæ.

Botanical name—*Cyamopsis psoralioides.*

Canal irrigated area—160,319 acres * in 1918-19. (Figures for the total area are not available.)

This is a hardy kharif pulse grown both for seed and as a fodder crop. It is very commonly grown for seed in Hissar and Ferozepore. The seed-rate is 8 seers for grain and 10 seers for fodder.

The yield when grown for grain averages about 10 maunds grain. The stalks are very woody when the crop is ripe. The leaves dry and drop on the ground, thus adding a good deal of vegetable matter to the soil.

This crop is a very useful heavy yielding fodder crop. Crops 5 feet high can be often seen in the canal tracts, where it is generally grown mixed with "juar" in various proportions, though sometimes grown alone. Cattle relish the green fodder, which has a high nutritive value.

Green manuring.

This is the most successful crop for green manuring yet tried at Lyallpur, being in this respect superior to sann-hemp.

SANN-HEMP.

Natural Order—Leguminosæ.

Botanical name—*Crotalaria juncea.*

Area—37,571 acres (for the five years ending 1919-1920†).

This crop is grown in small patches all over the Province. It is mainly grown for supply of fibre, the rope from it being useful in many ways to the zemindar. It is also grown to some extent as green manure. When grown both for fibre and as green manure it is sown thickly, the seed-rate being 25 seers or more per acre.

Preparation.

To secure a good crop the land must be thoroughly prepared. Under suitable conditions the plant reaches a height of 6 to 7 feet or

* Administration Report, Irrigation, Punjab, 1918-19.

† Season and Crops Report, Punjab.

more. When grown for green manure it is sown generally in early July and cut or ploughed in the first ten days of September. The ploughing of the green manure may be done easiest in the following way :—

A heavy "sohaga" is run over the crop in the direction along which ploughing will be done. When the crop is thus laid flat a furrow turning plough may be used to bury the crop. If the latter is not available, the "desi" plough must be used, but in this case there should be a man or two to assist by hand in putting the stalks in the furrow, so that the soil moved by the plough in making the next furrow may cover them properly. The field may then be left, after g ing over it with the "sohaga," until the green manure has decayed to some extent. It should be mentioned that it is advisable to water the "sann" a few days before ploughing in. Four or five weeks after the burying of the crop the cultivation required for the succeeding rabi crop may be begun.

Green manuring has been found to be very useful in bringing up the fertility of sandy soils. It must be remembered, however, that it is a costly process if the value of a fodder crop which could be grown on the same amount of water is taken into account * In the case of "guara" the crop can be grown early and ploughed into the soil in July, or later as in the case of "sann."

"Sann" for fibre.

The sowing and seed-rate is the same as when grown for green manure. The crop is allowed to grow till nearly ripe, *i.e.*, for 4 to 4½ months. It is then cut or pulled up by the roots and left exposed to the sun for 2 or 3 days. It is then tied into convenient bundles containing about 100 plants and stooked up for 2 or 3 weeks. The stooks are put in water about 2 feet deep with the lower part only in water. This is to give more time for the retting of the thick bark at the lower end of the stalks. The whole plant is then put in water and covered with stones and left for several days until the bark will separate easily from the stem. The plants are then dried and the fibre from each plant extracted by hand. This is a tedious process, and is generally done at odd times or during rainy days. A machine for extracting the fibre is being evolved by Mr. Finlow, Fibre Expert to the Bengal Government, and if successful would open out a new and important industry. The fibre is valuable and better than that of jute.

This crop drops its leaves during growth just like "guara," and being leguminous its roots add a store of nitrogen to the soil.

* See Agricultural Journal of India, Volume VIII, page 358, "Hot weather cultivation and green manuring in the Punjab," by W. Roberts.

SANKUKRA OR PATSAN.

Natural Order—Malvaceæ.

Botanical name—*Hibiscus cannabinus.*

Vernacular name—Patsan.

Canal irrigated area—5,000 acres.

In the Punjab this is grown to a very small extent, and mostly as a border to fields of sugarcane and cotton, etc. Its cultivation follows that of the major crop with which it is grown. If grown alone 10 to 15 seers of seed are sown in June or July, and the plants harvested in October and November. After drying in the sun the seed is separated by beating the plants on a piece of wood. The stalks after retting yield a useful fibre, which is, however, not so strong as "sann" fibre, and hence unsuitable for use as well ropes. The seed is sometimes used as cattle food, or oil may be extracted from it.

METHA AND METHI (*FENUGREEK*).

Natural Order—Leguminosæ.

Botanical name—*Trigonella Fœnum-græcum.*

"Metha" is a robust annual herb found wild in Kashmir and the Punjab, and is grown as a rabi crop chiefly for fodder. There is another variety known as "methi," which is a smaller plant and has smaller seed, and is mostly grown as a pot-herb and spice crop.

"Metha" is grown on "sailaba" lands, and on "chahi" lands chiefly in Ludhiana and Ferozepore districts in standing crops of cotton just like "senji." Seed is broadcasted and mixed into the soil by a "khurpa" hoeing. Sometimes it is sown after maize or "juar." Seed is sown at the rate of 10 to 15 seers per acre at the end of October or beginning of November. It requires 6 to 8 waterings, and is ready to cut for fodder in March or April. It gives about 250 maunds of green fodder per acre. Its fodder is considered to have a drying effect on milch cattle. Average outturn of grain is 7 to 8 maunds per acre.

Uses.

The seed is used as a medicine. The leaves are mixed with wheat or maize flour and made into bread. The green plant is used as a cattle fodder. In case of "methi," leaves both green and dried are used as a vegetable ("ság") and a spice. "Methi" of Kasur and Malerkotla has a special reputation as a spice throughout the Punjab.

INFERIOR MILLETS.

Natural Order—Gramineæ.

"Mandal" (*Eleusine coracana*)—Area 23,000 acres.

"Sawank" (*Panicum colonum*)—Canal irrigated area 7,000 acres.*

"China" (*Panicum miliaceum*)—Canal irrigated area 13,000 acres.*

"Kangni" (*Setaria italica*)—Canal irrigated area 4,000 acres.*

These millets are grown mainly on poor soils either for fodder or grain They are grown to some extent on irrigated land as early fodders.

MANDAL.

This is principally grown in the hills, being an important food in Simla and Kangra Districts. The largest areas in the plains occur in Sialkot, Jhang, Karnal, and Ambala. It prefers light soils, and its cultivation is similar to that of "juar," "bajra" or "china." Only 20 per cent. of the area is irrigated. The seed rate is 5 seers. Seedlings are raised in a nursery and transplanted, as in case of rice, or broadcasted.

It is sown in May with irrigation and transplanted when rains break. The crop receives 2 or 3 weedings, and is often top-dressed with manure after the first weeding. It suffers from excessive rain. A good year for rice is bad for "mandal." The yield in the plains is about 12 maunds grain and 30 maunds straw.

The grain is eaten by the poorer classes and is a staple food in the hills. It has excellent storing properties, being free from insect attack and not liable to become mouldy. For this reason it has been used for storage against scarcity and famine.

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* Average for three years 1914-15—1916-17 Administration Report, Irrigation, Punjab.

SAWANK.

This is the quickest growing of all the millets, and is supposed to ripen within 6 weeks or two months after sowing. It s found wild in most parts of the Punjab, and is also cultivated n small areas, but not as commonly as "china."

The seed-rate is 5 seers. It is often grown so as to supply cheap grain in August and September before "bajra" is ready. Hindus eat it on fast days.

CHINA.

This is of little economic importance except as an early fodder or grain crop. For this purpose it is sown in March at the rate of 5 seers per acre and ripens in May. The fodder is relished by cattle and horses The grain is used for making "chapatis" in the hills.

KANGNI.

Grown mostly in the hills. It has a wider range as regards season than the other millets, and is often grown after famines, when a quick return is required.

The crop is often sown on manured land near the villages in hill tracts. The seed-rate is 3 to 4 seers. Birds are very fond of the seed and do much damage to the ripening crop.

INDIGO.

Natural Order—Leguminosæ.

Botanical name —*Indigofera tinctoria*.

Area—90,837 (1917-18) : 36,000 acres (1908-09).

Indigo is grown for the sake of the "dye" which i extracted from the leaf. The area increased during the war, but it is now showing signs of falling off again.

The seed is generally sown in March or April (*Chaiti*), though it is sometimes sown in the rains (*Asahri*), and in the latter case is left to give a ratoon crop the following summer.

The March-April crop is cut in August. If the land is not ploughed up, new shoots appear and a crop of seed is obtained in December. As a rule a rabi crop follows the indigo, and the latter being a legume improves the soil.

Sowing.

Weeding.

Seed is sown broadcast at the rate of 2 to 3 seers on a moist seed bed and covered with a "sohaga." It is important to keep the crop free of weeds. Generally two weedings are given.

Cutting and steeping.

Generally two cuttings are taken. The plants are fermented in vats. The indigo industry is carried on on a large scale in Behar. For details of manufacture see Watt's Dictionary of Economic Products. The dye is used by Sikhs for dyeing the hair in addition to its main use for dyeing cloth.

TURNIPS

Natural Order—Cruciferæ.

Botanical name—*Brassica Rapa.*

Vernacular name—Sag, gonglu, shalgham.

Canal irrigated area—200,000 acres.*

Turnips are an important and much valued fodder crop grown in the rabi season chiefly in Shahpur, Jhang, Multan, Montgomery, and Lyallpur. It provides fodder for cattle after "chari" is finished and until wheat "bhusa" is available.

There are two varieties recognized by zemindars, *viz.*, a white and a red type, the former being generally preferred.

The crop does best on a free working loam which is manured with well-rotten farmyard manure. Seed is sown at the rate of 2 to 3 seers. Early sowings occur at the end of August or early September, and late sowings about the middle of October. The crop should receive five or more waterings during growth. Seven to nine weeks after sowing the leaves are ready to cut as fodder. A month later the whole plant top and root is taken out. It is fed to cattle alone or mixed with "bhusa" after chopping with the "toka." A good crop should provide plentiful leaf and give a substantial root crop as well.

Plants not removed for fodder will seed in April; but this seed is of poor quality and gives a poor root crop if sown. The process known as "dakk" enables better seed to be obtained. This consists in removing the leaves and transplanting it after cutting off about a third from the lower part of root. Sometimes the root is cut by sickle without removing the plant. This is known as "datri wala dakk," and though inferior to the former method is easier and less troublesome, and it is said the crop is immune to attack by aphis (*t-la*) when thus treated as compared to transplanting.

LINSEED.

Natural Order—Lineæ.

Botanical name—*Linum usitatissimum.*

Vernacular name—Alsi.

Area—35,000 acres.

Linseed has been grown in India from very ancient times. Nowadays it is mostly grown in the Central Provinces, Behar, and the United Provinces.

In the Punjab it is mainly grown in the submontane tracts, and chiefly in Kangra, Gurdaspur, Hoshiarpur, and Sialkot.

Linseed is grown in India for seed. In Europe and America it is mainly grown as a fibre crop. Efforts to grow linseed for fibre in India have so far resulted in failure. A persistent effort was made in this direction in Behar from 1907 to 1910, when a Belgian expert was engaged. The industry never attained large proportions, and practically no export of the fibre or flax exists now.

The plant branches freely in India. It prefers heavy soil, and is generally sown alone. Sometimes a few rows are sown with gram or wheat or along the borders of the fields.

Seed is sown at the rate of 6 to 8 seers per acre in a wel prepared seed-bed in October or November. It ripens in March or April. The crop is carried to the threshing floor as soon as ripe, as "shedding" of seed occurs freely when plants are ripe. After drying it is generally threshed by manual labour. It yields 5 or 6 maunds of seed, which in the country "kohlu" gives about 25 per cent. oil. The cake is highly valued as cattle food, and is often obtainable from Calcutta at a price which makes it cheaper than any other cattle food even after paying cost of carriage to the Punjab.

OATS.

Natural Order—Gramineæ.

Botanical name—*Avena sativa.*

Vernacular name—Jawi.

Canal irrigated area—25,000 acres.

This crop, though important in Europe, is comparatively unimportant in the Punjab. It is grown mainly near Remount Depots and Cantonments or on Stud Farms, where it is regarded as a very valuable fodder for horses. It is grown mostly in the districts of Delhi, Hissar, Ambala, Karnal, Shahpur, and Montgomery.

The cultivation is similar to that given, wheat or barley. The seed-rate is from 24 to 32 seers, and the crop receives 2 to 3 waterings after sowing. It is fed green in February and March. If cut and dried when the seed is beginning to fill, it forms oat-hay, and can be stored conveniently in this form. If the seed is allowed to ripen in April, the crop is cut before it is dead ripe to prevent loss by "shedding" of seed. It is threshed like wheat by means of bullocks, though sometimes this is done by hand as in the case of rice. The yield of grain is about 15 maunds with 30 maunds of "bhusa." Oats in India has a very small thin kernel as compared to that generally grown in Europe.

Newly imported varieties, such as French oats, remain green up to May and give very little seed. They grow rankly and give heavy crop of fodder. Seed oats is a valuable concentrated food for horses.

Oats is sometimes very seriously attacked by "smut." Treatment of the seed with copper sulphate before sowing is a safe and certain remedy.

LUCERNE (*ALFALFA.*)

Natural Order—Leguminosæ.

Botanical name—*Medicago sativa.*

Vernacular name—Lusan.

Canal irrigated area—25,000 acres.

This is a leguminous fodder crop widely grown in small plots over most of the Province. It is perennial and gives from 4 to 7 cuttings per annum. The most vigorous growth is during the rains. It is much valued as a green fodder for horses,

and is therefore grown largely near Cantonments and Remount Depots.

Lucerne seed is apt to be unreliable, and germination tests are advisable before sowing. Good seed is plump, glassy and rich brown in colour. The seed costs from Re. 1-8 to Rs. 5 a lb.

Sowing.

Several methods are in vogue, the most common being broadcasting at the rate of 16 lbs. per acre The seed is covered lightly by means of light "sohaga" or by a wooden rake. It is best sown in October. The crop should be watered every fortnight in winter and every 8 days in summer if rain has not fallen.

Well rotted farmyard manure should be applied after every third cutting. If sown in ridges, the seed-rate is 10 lbs, the ridges being 24 inches apart. The crop should be hoed after every cutting to keep down weeds.

Seed is best produced in the cold season. To encourage seed formation, water is sparingly applied and withheld altogether as seed ripens. An average cutting weighs 120 maunds per acre.

ONIONS.

Natural Order—Liliaceæ.

Botanical name—*Allium Cepa.*

Vernacular name—Piaz.

Canal irrigated area—1,000 acres.

This is mainly a garden crop in the Punjab, though in other parts of India, such as the Bombay Presidency, it is extensively grown as a field crop.

Seed is sown in the nursery in October and November, and transplanted in January. Two main varieties are grown *viz.*, a large red and a silvery white variety, the former being by far the most common. Onion seed is propagated as follows:—

Well developed bulbs are selected and the top part cut off to the extent of a quarter of the bulb. The latter is generally divided in two and planted in well prepared and manured soil. Several shoots with flowering heads should spring from each bulb. These will ripen in April and be fit for sowing in October. Two pounds of seed in a nursery will give seedlings for one acre. The nursery should be watered three

days previous to transplanting, as this facilitates removal of seedlings. The seedlings are planted in well prepared soil, which is watered immediately afterwards, and again in 4 days' time. Subsequent waterings are given as required. In all 5 or 6 waterings are necessary. The yield averages 300 maunds per acre.

Garlic (*Allium sativum*) is cultivated in the same way as onions.

MELONS.

Natural Order—Cucurbitaceæ.

Botanical name—*Cucumis Melo.*

Vernacular name—Kharbuza.

Canal irrigated area—77,000 acres.*

The melon from an agricultural point of view is the most important species of the genus Cucumis. There are a very large number of varieties and forms, and some districts, such as Jullundur and Ferozepore, are famous for the quality of the melons grown there. It is grown on the sandy banks of Indian rivers, and also as a cultivated field crop both irrigated and unirrigated. It is sown in February and March and ripens in May and June. The seed-rate is about 2 seers per acre, and the seed is sown broadcast. In the colonies it is often grown with cotton, the field being manured beforehand. The fruit is much appreciated during the early hot weather months. If a suitable market is at hand, the crop is a very paying one, and often gives a gross return of 200 to 400 rupees.

Other common varieties of Cucurbitaceæ are the water-melon ("tarbuz" or "hadwana") *Citrullus vulgaris*, cucumber (or "khira") *Cucumis sativus*, and long-melon ("tar" or "kakri") *Cucumis Melo, Var. utilissima.*

TOBACCO.

Natural Order—Solanaceæ.

Botanical name—*Nicotiana Tabacum.*

Vernacular name—Tamaku.

Area—60,000 acres.

Tobacco is grown mainly in parts of the Eastern Punjab such as Jullundur and in Attock. It is important only in

* Average for the three years ending 1916-17—"Administration Report, Irrigation," Punjab.

these tracts, though it is grown on a small scale by Mussalmans and Hindus all over the Province.

Tobacco is sown in a nursery, and afterwards transplanted into the field. One hundred square feet of nursery is sufficient for an acre. It is regarded as an intensive crop, and only grown on good soil with plenty of manuring. It is sown in October or November and transplanted in February, when seedlings have 4 leaves. The distance between plants is from 18 to 24 inches. The crop gets frequent hoeings and from 7 to 9 waterings.

Curing.

When the leaves begin to turn yellow, they are stripped off and dried for 2 or 3 days. They are then heaped, and when slightly heated tied into bundles. The bundles are again heaped together and turned every second day. Curing takes about 14 days. Each bundle weighs 1½ to 2 lbs. Tobacco cured in this way is used for "hookah" smoking, and is of a brownish black colour. It is sometimes mixed with molasses before being used in the "hookah." The tobacco grown in Jullundur is said to be of good quality, and quite possibly a good deal could be done in developing the industry and producing leaf suitable for cigarette smoking.

PEAS.

Natural Order—Leguminosæ.

Botanical name—{ *Pisum arvense* (Field pea).
Pisum sativum (Garden pea).

Vernacular name—Mattar.

Canal irrigated area—14,000 acres (average for three years from 1914-15 to 1916-17).

Both are rabi crops widely distributed over the Province.

Field pea.

The field pea is a much smaller plant and has smaller seed than the garden pea. The former is, however, much hardier. It is grown mainly on "sailaba" land, and almost entirely as fodder. It receives very little cultivation, generally one or two ploughings only, and no manure. The seed is generally sown broadcast, and sometimes by "nali" at the rate of 20 to 30 seers per acre. If sown in October, the fodder is available in February

and seed in April. The crop is harvested by pulling from the ground or by sickle. It yields about 6 or 7 maunds of grain and 200 maunds green vegetable, specially valued for milch cattle.

Garden pea.

The garden pea is generally sown on ridges at the rate of 8 to 12 seers per acre. In Kashmir it is sown broadcast like the field pea. This variety can be sown at the end of August or early September, and then gives green fruit in December or earlier. Ordinarily it is sown in October, and produces fruit in January or February. When the plants are 6 inches high, dry sticks are put in the ground for the plants to climb on. Seven to ten waterings are given in irrigated land. The garden variety should be sown in well cultivated and manured soil, as it is a delicate plant compared to the field pea. Many varieties of garden peas are on the market.

Uses.

The green pods are cooked whole as a vegetable by Indians. The green seeds are also cooked and appreciated by Indians and Europeans. The ripe seed is used whole or split as "dal."

POTATO.

Natural Order—Solanaceæ.

Botanical name—*Solanum tuberosum.*

Vernacular name—Alu.

Canal irrigated area—100,000 acres.

Distribution.

Potato is principally a garden crop in the Punjab. It grown in the montane and submontane tracts of the Province as well as in the plains near big towns. In the plains generally two crops of potatoes are taken in one year on the same land. The first crop is sown in the month of September and harvested in the months of December-January, while the second is sown in January-February and gathered in the month of May. After the second crop is removed the land is either allowed to remain fallow till September or put under maize for fodder or some other quick growing vegetable crop in the rainy season.

Soil.

Sandy loam is the best soil for potato growing.

Manuring.

Potato land is heavily manured in the month of August or early September a few days before sowing.. About 50 cart loads of farmyard manure are applied per acre.

Cultivation.

Usually 6 to 7 ploughings are given in order to secure a fine seed-bed.

Method of sowing

The seed potatoes are dibbled about 3 inches deep at a distance of 9 to 12 inches from each other on ridges about 1½ foot apart. For the September sowing whole tubers of medium size are planted, and the seed rate varies from 12 to 15 maunds per acre according to the size of the tubers ; while in the February sowing sufficiently big cut-pieces of tubers, each having 2 or 3 buds, are planted, and

the seed rate is about 8 maunds per acre. The cut-pieces are not sown in October, as they are liable to rot.

The seed for February sowing is obtained from the hills, as the fresh potatoes of January harvest of plains will not germinate, while for September sowing small tubers from the May harvest are picked up and stored for seed. In the hills, where only one crop is taken each year, potatoes are sown in the month of April and dug up in the months of September and October.

Hoeing and earthing.

After the first irrigation, which is given 7 to 10 days after sowing, weeding is done, and a thorough hoeing is given after second irrigation, when the plants are about 6 inches high; one more hoeing and earthing is given later on with the third irrigation. It receives about 10 irrigations in all.

When the tubers have developed properly the leaves turn yellowish. The crop is then carefully dug up by means of khurpa so as not to injure the tubers. The average yield is about 100 maunds of potato tubers per acre.

Varieties.

There are many varieties grown in the Province, but "gola," "surkha" and "phallua" are the must common.

Gola.—It is medium sized, rough skinned, brownish potato having a round shape. It is considered a heavy yielder and is extensively cultivated in the Sialkot District. Seed tubers are obtained from the hills near Dehra Dun and Quetta.

Surkha.—Red in colour and is much liked by Indians on account of its fine flavour. It is obtained from Patna.

Phal ua.—It comes from Farukhabad in the United Provinces. Its tubers are whitish and it is a heavy yielder. It is much grown at Amritsar.

Storage of seed potatoes.

The potatoes kept for seed are best stored under dry sand in well ventilated rooms They should be examined at least once a month, rejecting the rotten tubers and preserving only those which are perfectly sound. This is a useful method both against potato moth and fungus rot.

Cost of cultivation.

The cost of cultivation is as follows :—

Outlay—

	Rs.	a.	p.
Six ploughings and sohagaings	10	0	0
Manure 50 cart loads	50	0	0
Ridge making and planting	6	0	0
Cost of 8 maunds of seed at Rs. 8 per maund ...	64	0	0
One weeding	3	0	0
Two hoeings	4	0	0
One earthing	6	0	0
Ten irrigations (well).	40	0	0
Harvesting	12	0	0
Revenue	5	0	0
Total ...	200	0	0

Return—

100 maunds of potatoes at Rs. 3 per maund ..	300	0	0
Profit	100	0	0

Trials of Scotch potatoes.

Potatoes are propagated by vegetative reproduction, and after a time the tubers lose their vigour and deteriorate in quality and yielding capacity. To remedy this, rejuvenation is necessary by sexual reproduction. A case in point is the potato growing of Simla Hill States. Since their first introduction about 40 years back the potatoes have been propagated there from tubers year after year. The result is that they have deteriorated, and their cropping and disease-resisting powers have been much reduced. To replace these potatoes the Agricultural Department some few years back introduced some varieties of Scotch potatoes which had been raised from seeds comparatively recently. The results so far have been very promising, and there is a great demand for the newly introduced varieties for seed.

CHILLIES OR LAL MIRCH.

Natural Order—Solanaceæ.

Botanical name—*Capsicum frutescens.*

Canal irrigated area—4,000 acres.

Chillies are widely grown as a garden crop all over the Province, especially in the districts of Ludhiana, Ambala and

Karnal. It thrives best in light sandy soil which is in good heart. Two seers of the seed is sufficient to sow a nursery for one acre. The seed is sown in October in a sheltered position and seedlings transplanted in February and March. Broadcast sowing in the field is also practised, but does not give as good results as transplanting.

The land before transplanting is generally ploughed three or four times and manured with about fifteen cart loads of manure. When the seed bed is prepared the plants are put in in bunches of three or four at a distance of 18 inches from the next bunch, and a similar distance from the adjoining row. The field after transplanting is given water. Application of the latter to the nursery also facilitates removal of seedlings for transplanting. Subsequent irrigations are given every ten days or a fortnight as required. The plants are earthed up in the rows when established.

Fruit forms in July and ripens in October or November.

The yield averages about 40 maunds of green chillies or 10 maunds of dried fruit, which sells at from ten to fifteen rupees per maund. The plants are often damaged by white ants in the field or garden. Crude oil emulsion kept in a cloth bag in the irrigation channel, where it can mix freely with irrigation water, has proved useful in checking this evil.

NOTE.—Of the canal irrigated area 1,000 acres are grown respectively on the Western Jumna and the Upper Bari Doab Canals.

SENJI OR INDIAN CLOVER.

Natural Order—Parviflora.

Botanical name—*Melliotus parviflora.*

Canal irrigated area—400,000 acres.

Senji is an irrigated rabi fodder crop grown widely on perennial canals and on well land in the Province. It is usually sown in the 'vadh' of maize or cotton during the later stages of the growth of these crops, and thus gets the advantage of shade during the early period of its growth. The water given to it also assists the shading crops, which might otherwise be grudged the late watering. Sowing takes place usually in the first fifteen

days of October. The following are the common rotations in which it enters :—

Maize-Senji—Sugarcane ; wheat or cotton.

Maize-Senji—Cotton ; wheat.

Cotton-Senji—Wheat ; toria.

The seed rate is from 20 to 25 seers per acre. The seed is beaten lightly before sowing in order to remove the husk. The seed is sown just after irrigation and trodden in by men walking over the ground. The first irrigation after sowing is generally given within ten days, and water is afterwards applied as required generally every 15 or 20 days. Total number of waterings is from 5 to 7. The crop therefore requires much more water than wheat, and the area sown per square of land rarely exceeds two acres even where the water supply is good. The crop is ready for cutting when in full flower after seed formation has started. It yields about 200 maunds of green fodder per acre. It forms an excellent fodder for cattle and milch cows, but should be fed mixed with bhusa or some dry fodder, as otherwise it is apt to cause tympanitis. The crop following senji is generally luxuriant in growth owing to the store of nitrogen left in the soil by the senji crop.

SHAFTAL OR KABULI CLOVER.

Natural Order—Leguminosæ.

Botanical name—*Trifolium resupinatum.*

Shaftal is a rabi fodder crop experimented with in recent years by the Agricultural Department and introduced from the North-West Frontier, where it is largely grown. Its main advantage over 'senji' lies in the fact that it will give two or more cuttings, whereas senji gives only one. It also belongs to a better class of leguminous plants than senji.

Second cuttings of this crop sometimes extend to end of April or early May, and waterings given at that period are sometimes charged for in the kharif season, thus putting a double water rate on the crop. This crop should be classed for water rates on the same basis as senji, for if only two cuttings are taken, the amount of water given is certainly no more than that given to the latter. The seed rate for shaftal is 5 or 6 seers per acre. It is best sown on a fine moist and prepared seed bed. It is quite a good practice also to sow it as a mixture with senji. In

the latter case 4 or 5 seers of shaftal is mixed with 20 seers of senji and sown as described above under 'senji.' Shaftal makes an excellent green fodder for cattle and horses. Experiments made at Quetta indicate that it will also make very good hay.

Shaftal is sometimes attacked by a kind of red rust, but on cutting and irrigating this mostly disappears.

BERSEEM OR EGYPTIAN CLOVER.

Natural Order—Leguminosæ.

Botanical name—*Trifolium alexandrinum.*

This crop is grown extensively in Egypt, where out of a cultivated area of three million acres one million is returned as berseem. It has been tried in various parts of the Punjab, on military farms, and in other places with variable success. It is said to flourish well in Sindh, where considerable areas are grown, notably at Mirpur Khas and Hyderabad.

Seed rate cultivation and sowing is similar to that of senji, but a somewhat smaller seed rate is employed, and the seed is soaked for 24 hours before sowing. Berseem gives from three to five cuttings. If seed is required, only two cuttings should be taken. Seed can be obtained from the Agricultural Officer, North-West Frontier Province. The very high yields per acre of Egyptian cotton is said to be largely due to the fertilizing properties of this crop.

See Pusa Bulletin No. 66.